STUDIES ON *ERYSIPHE CICHORACEARUM* DC. INFECTING COMPOSITAE

ABSTRACT

OF THE

THESIS SUBMITTED FOR THE DEGREE OF

Doctor of Philosophy

IN

BOTANY

MD. SHAHID PERWEZ

DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
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A B S T R A C T

Powdery mildew of composites caused by Erysiphe cichoracearum Sphaerotheca fuliginea and Oidium spp. take a heavy toll of composites throughout north India. These pathogens are invariably being found in conidial stages. This make their identity rather difficult, they have been diagonised on the basis of mycelial and conidial characters. Present studies have been restricted to E. cichoracearum, which appears to be more common on the members of Compositae than other pathogens.

Perithecia of S. fuliginea have been collected from Chrysanthemum carinatum and Helianthus annuus in nature.

In host range studies, five isolates of E. cichoracearum obtained from five different composites; seven of S. fuliginea and three of Oidium spp. have been tested against cultivated and wild composites as well as non-composites, both in glasshouse and field. It has been observed that the Cineraria sp., Dahlia variabilis, Lactuca sativa and Zinnia elegans are susceptible to the E. cichoracearum isolates from composites but failed to produce symptoms against non-composite isolates. S. fuliginea and Oidium spp. developed diseases only on their respective hosts except Cacalia coccinia, which gives positive results against the isolates of S. fuliginea from Xanthium strumarium. The isolates of E. cichoracearum from two non-composites failed to produce disease on composite plants.

Helianthus annuus is the common host of both E. cichoracearum and S. fuliginea under Indian climatic conditions.

Varieties of the different cultivated composites have been found highly susceptible to resistant to the isolates of E. cichoracearum obtained from various composites.

The range of optimum temperature i.e. 15-25°C for germination of conidia of E. cichoracearum obtained from Dahlia variabilis and Zinnia elegans, on the other hand, the relative humidity 90-100 percent have been found optimum for germination of conidia of this pathogen.

Perithecia obtained from C. carinatum and H. annuus despite being subjected to different treatments have failed to discharge ascospores.

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CERTIFICATE

This is to certify that **Mr. Md. Shahid Perwez** has worked in this Department as a Research Scholar under my supervision and guidance. His work on the **"Studies on Erysiphe cichoracearum DC. infecting Compositae"** is upto-date and original. He is allowed to submit his thesis for the consideration of the award of the degree of Doctor of Philosophy.

Mohd. Akram

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Md. Shahid Perwez.

(MD. SHAHID PERWEZ)

C O N T E N T S

Chapter 1

Introduction

C H A P T E R - 1

INTRODUCTION

1.1. FAMILY COMPOSITAE: The Compositae family was the last family of dicotyledonous by Engler. It has been thought at or very near to the peak of dicot evolution. This family Compositae is considered as the most advanced family of flowering plants on the basis of the following characteristics:-

(1) Mostly the Compositae are herbaceous, some are shrubs while a limited numbers are of trees.

(2) The presence of about 950 genera and nearly 20,000 species or roughly about the 10 percent of the known dicotyledonous plants. These are cosmopoliton in distribution and they grow in varying types of climatic conditions.

Economically the family is of great importance, large number of plants are extremely ornamental viz. Helianthus annuus, Tagetes erecta, Chrysanthemum spp., Centaurea spp. and Carthamus tinctorius being cultivated in gardens, homes and other places. Some members are important as sources of food to man as lettuce (Lactuca spp.), globe artichoke (Cynara spp.), endive (Cichorium spp.), salsify (Tragopogon spp.) and chicory (Cichorium spp.). Many members are noxious weeds and others are medicinally

important e.g. Artemisia absinthium and the root of Doronicum roylei are used as aromatic tonics. Artemisia cina, A. maritima and A. nilagarica yield "santonine" which is used for expelling worms. Marticaria chamomilla (Midteranean) is the source of "chamomile" a medicine; other medicinal plants are Anthemis nobilis, Arnica montana, Calendula officinalis, Cnicus benedictus, Filago germanica, Petasites hybridus, Tanacetum vulgare, Vernonia anthelmintica, Centipeda arbicularis, Solidago spp., Blumea lacera, Sphaeranthus indicus, Eclipta alba, Glossogyne pinnatifida, Siegerbackia orientalis, Taraxacum officinale and Sonchus oleraceus etc.

Some most economically important plants are as follows:-

(1) Helianthus annuus (Sunflower):- Exact place of origin is unknown. Its native is probably South America and now it has been cultivated in various parts of the world. The U.S.S.R., Romania and Argentina are large producers of Sunflower seeds. In recent years Sunflower has become an important crop in the U.S. and Canada. The seeds of the common Sunflower contains 32 to 45 percent of a light golden yellow oil equal to olive oil in its medicinal and food value. It is an excellent salad oil and is used in margarines and as lard substitutes. The seeds are a good bird and poultry food, the oil cake is excellent for stock, and the entire plant is often grown for ensilage. The oil has semidrying properties which render it useful in the paint, varnish

and soap industries.

(2) Helianthus tuberosus (Jerusalem artichoke):- Its native place is North America and has been cultivated by the Indians for centuries. The tubers, which somewhat resemble potatoes, but with larger eyes, are cooked, pickled or eaten raw. The carbohydrate food is in the form of inulin, which is a good food for diabetics, and is also as a source of levulose and industrial alcohol. The plants are also grown as a forage crop and weed eradicator.

(3) Carthamus tinctorius (Safflower):- It is a very important Asiatic dye plant and is a native of India but is now widely distributed in most warm countries. Not only are the flowers used for a dye, chiefly in coloring food, but the seeds furnish an edible oil and the leaves are used as a salad vegetable. The plant is grown to some extent in the United States for the oil. The yellow or orange thistle-like heads are picked in dry weather, dried out, and pressed into cakes. Both a red dye, used for fabrics and rouge, and a yellow dye are obtained. Safflower is grown economically for the dye in Southern France and Bengal.

(4) Lactuca sativa (Lettuce):- Lettuce, a native of Southern Europe and Western Asia, is descended from the wild lettuce (L. scariola) a common weed of roadsides and waste-land in both the old and new worlds. It is another herbage vegetable of great antiquity. The plant produces a basal rosette of leaves, and later in the season a stalk with flowers and fruits. Lettuce has

a milky juice. It is of little value as a food, except for its vitamins and iron salts. Formerly it was cultivated only in home gardens. Now it is an important commercial crop and thrives best in sandy or loamy soil and required cool weather and not too much sun.

(5) Dahlia pinnata Cav. (Dahlia):- From the tubers of Dahlia pinnata, a polysaccharide, inulin, is used for commercial preparation of fructose.

(6) Matricaria chamomilla (German chamomile):- Chamomile is an old-time remedy obtained from Matricaria chamomila. This daisy like plant, a native of Eurasia, is cultivated in the United States and elsewhere. The dried flower heads contain an essential oil. Infusions of chamomile are used as tonics and gastric stimulants. The flower heads of the Russian or garden chamomile (Anthemis nobilis) are used for similar purposes and also in poultices for sprains, bruises and rheumatism.

(7) Chrysanthemum spp.:- The bark of C. coronarium, is a pergative and also used to cure syphilis. The plant when mixed with black pepper is given in gonorrhoea.

(8) Inula spp.:- It includes about eight Indian species. I. grantioides is used in aesthema disease. I. graveolens is used as diuretic. I. helenium is used in chronic bronchitis and rheumatism. I. racemosa and I. roylana also have medicinal uses.

1.2. THE POWDERY MILDEWS: The word powdery mildew was recognized and named as early as 1753 by Linnaeus, when he gave the binomial Mucor erysiphe to a white fungus on the leaves of Humulus, Acer, Lamia, Galeopsis and Lithospermum. He did not describe or illustrate either the conidial or perithecial stage. Why he called it Mucor or Erysiphe is not clear. The pathogen which causes powdery mildew comes under the family Erysiphaceae (Halsted, 1884). Riley (1886) may have been the first to point out clearly the differences between the downy mildews to the perenosporaceae and powdery mildews to the Erysiphaceae.

The powdery mildews fungi, including 20 genera and probably about 400 species compose the Erysiphaceae family. The members of the family are easily recognizable since they form a white powdery appearance due to the production of enormous number of hyaline conidia on the surface of the host, which can be seen by the unaided eye.

Erysiphaceae are obligate parasites of ascomycetous fungi with white (colourless or hyaline) hyphae and colourless one-celled ascospores borne in asci enclosed in black non-ostiolate perithecia on the surface of living plants. This definition based on the perfect stage has limited use because most collections do not contain perithecia. A better working definition is that, powdery mildews are those fungi with white superficial hyphae on the aerial parts of living plants, with large one-celled conidia produced terminally on isolated aerial

unbranched conidiophores with haustoria in the epidermal cells of their hosts. A combination of these definitions would be better than either alone. Powdery mildews grew principally on foliage of angiosperms and cause damage on a wide variety of crops. The fungus attack stems, flowers and fruits. Firstly the fungus show very mild infection producing small patches on the host, later it become chlorotic and may kill the whole plants as a result of severe infections. Fruits on infected plants ripen prematurely and lack the texture, flavour and sugar-contents. Sometimes fruits too do not set or remain smaller in size.

Chapter 2

Review of Literature

C H A P T E R - 2

REVIEW OF LITERATURE

2.1. LOSSES: Large number of cultivated and wild species of different families have been recorded as the hosts of the members of Erysiphaceae. Due to this disease a considerable amount of damage has been recorded and at times it exceeds 20 percent, Jagger (1926); Milbrath (1927) and Mckeen (1954) reported heavy losses in the yield of Muskmelon due to powdery mildew, while Szembel (1930) and Tafradzhiiski (1959) reported that it was very destructive to cucumber. Jensen (1951) pointed out that powdery mildew caused 52 percent reduction in the yield of barley, while on the other hand Last (1957) estimated it to be 68 percent.

The reduction was of 83 percent in gooseberry reported by Cork (1965). The most widespread and destrous losses attributed to a powdery mildew was on grapes in France viz. 33 to 90 percent losses had been recorded (Arnaud and Arnaud, 1931) and 80 percent in Peaches by Fikry (1936). Heavy losses due to this group of fungi had also been reported by Cannon (1962) on Potatoes; on mint by Ganguly and Pandotra (1963-64); on Tobacco by Wober (1959) and Cole (1963) and Moore (1956) on Peppers.

2.2. IDENTIFICATION: Majority of powdery mildews, including species attacking composites, seldom produce perfect stages, the perithecia, are of limited value in taxonomy of powdery mildews,

because most collections do not contain them, only 13 percent of 515 collections listed by Gardner and Yarwood (1974) contained perithecia. Tropical and subtropical regions contain many powdery mildews but perithecia are uncommon (Hansford, 1961; Bessey, 1961; Clare, 1964 and Blumer, 1967). Laibach (1930) indicates that the old leaves, a low state of host nutrition, a dry atmosphere and low temperature favour perithecium formation. Continuous culture in the glasshouse may lead to loss of perithecium formation (Mamulk and Wettzien, 1973). Two sexually compatibile strains are necessary for perithecium formation in many cases (Smith, 1970) and this could explain the long interval between the discovery of the conidial and perithecial stages of Uncinula necator on grapes in Europe (Cauderie, 1893) and Erysiphe polygoni on beet in U.S.A. (Coyier et al., 1975). Clearly certain geographic areas favour perithecium formation. The perithecial stage of Erysiphe cichoracearum on Potato (Menzies, 1950); on Cucumber (Randall and Menzies, 1956). Perithecia of E. polygoni on redclover were first found in the U.S.A., in the Pacific Northwest (Mains, 1923). Not only the host species but also its variety may be important, thus perithecia of E. cichoraccarum were found only on certain varieties of Cucumber (Randall and Menzies, 1956). Perithecia of E. polygoni occur abundantly on Trifolium longipes but rarely on T. pratense in California.

In the absence of perfect stages, the identification is mostly done on the basis of mycelial and conidial characters:-

(1) Mycelium:- White (hyaline or colourless) parasitic mycelium on the surface of living leaves, still distinguishes the Erysiphaceae from other fungi. With a few species as Sphaerotheca lanestris and Sphaerotheca mors-uvae, the mycelium is dark or darkens with age and may become almost black. Most Erysiphaceae have only superficial mycelium. Phyllactinia has mostly external mycelium but sends branches through the stomata to the mesophyll tissue where haustoria are formed, Uncinula polychaeta forms internal mycelium, whereas the mycelium of Erysiphe graminis, E. cichoracearum and S. fuliginea is normally external but has been induced to become internal (endophytic) by removing the epidermis (Salmon, 1906a), by heat treatment (Salmon, 1906a and Jarvis, 1964) and by translocated heat treatment (Jarvis, 1964).

Powdery mildews are among the relatively few groups of plant pathogens apparently never recorded on roots except for E. epigea on grass roots (Leveille, 1851).

(2) Conidiophores:- Most of the white powdery appearance of Erysiphaceae is due to conidiophores and conidia borne on the mycelium but with such as E. trina on Quercus spp. and the pannose mycelium of S. pannosa on Rosa and Prunus persica, there are no or few conidia and the mycelium seems felty or glistening them powdery. No conidia are known for E. aggregate (Yarwood, 1973); Podosphaera major (Blumer, 1967).

Conidiophores of Erysiphaceae range in length from about 60 um (Clarle, 1964) for M. alni on the upper surface of oak leaves

to 670 um for S. humuli on the lower surface of strawberry leaves (Yarwood and Gardner, 1970) or even 700 um for Leveillula sp. (Salmon, 1906b). Chain forming conidiophores such as Erysiphe cichoracearum are usually longer than conidiophores where the conidia are borne singly such as E. polygoni. With chain forming species the number of cells of the chain may range from three, as in E. polygoni to 12 or more as in P. leucotricha (Yarwood, 1937). At high humidity, E. polygoni type conidiophores may form chains of conidia (Neger, 1901; Salmon, 1900). Conidiophores are commonly longer on the lower leaf surface than on the upper and longer on leaves with hairs than on glabrous leaves (Yarwood and Gardner, 1970). Both chain forming and non-chain forming conidiophores show a diurnal periodicity of development (Childs, 1940; Yarwood 1936a) but no diurnal periodicity was noted for E. graminis (Pady et al., 1969).

The principal types of conidiophores are those with a swollen basal cell Vs those with unswollen basal cells, twisted basal cells Vs not twisted, conidia borne singly Vs borne in chains, with fibrosin bodies Vs without fibrosin bodies and those with conidia of various shapes (Yarwood, 1973).

(3) Conidia:- When conidia are used in taxonomy, it is the shape (Alcorn, 1968), size of conidia which is most commonly used to characterize species (Allison, 1934; Weltzien, 1963). Size of conidia is fairly constant for a given host in a given environment (Blumer, 1922; Bouwens, 1927) but varies greatly with host

nutrition (Neger, 1902), age and vigourity of host leaves (Neger, 1902; Fischer, 1957), nutrition of host leaves (Zwirn, 1943), season (Homma, 1937), humidity (Bouwens, 1924; Neger, 1901), host species (Bouwens, 1924; Homma, 1937) and undetermined factors (Yarwood, 1957). DeCandolle (1805), Salmon (1900), Blumer (1933 & 1967) and several others either omitted consideration of the conidial stages of Erysiphaceae or placed conidial stages in the genus Oidium.

(4) Fibrosin bodies:- Presence and absence of fibrosin bodies in the conidia of the pathogen, as suggested by Homma (1937), Clare (1958 & 1964), Kable et al. (1963) and Jhooty (1967), is taken into consideration for identification. Well developed fibrosin bodies occur in the conidiophores and conidia of most Sphaerotheca and Podosphaera and some Uncinula spp. but do not occur in Erysiphe or Microsphaera (Swada, 1914).

(5) Germination of conidia:- Neger (1902), Clare (1964), Hirata (1942 & 1955), Kable et al. (1963) and Zaracovitis (1965) have distinguished some Erysiphaceae by the method of germination of the conidia. E. betae (E. polygoni) formed short germ tubes with lobed appressoria; S. fuliginea produced short germ tubes with forked appressoria and S. macularis given out long germ tubes without appressoria (Zaracovitis, 1965). Conidia of E. polygoni, M. alni and U. necator germinate at close to 90 percent relative humidity (Delp, 1954), while those of S. pannosa and Podosphaera leucotricha require approximately 100 percent relative humidity

for germination on glass slide (Brodie, 1945). The germ tubes of some species are phototropic (Neger, 1902) though those of E. polygoni may be positive or negative (Yarwood, 1957). The host may greatly stimulate the germination of conidia (Jhooty, 1971; Yarwood, 1936a).

The best documented powdery mildew pathogen of the family Compositae is E. cichoracearum. This is recognized by its two-spored asci and basally inserted appendages which are much longer than the diameter of the ascocarp. It resembles S. fuliginea in possessing conidia in long chains which has possibly led to confusion in some reports. Conidia of S. fuliginea produce forked germ tubes whereas those of E. cichoracearum form well differentiated appressoria (Zaracovitis, 1965). The pathogen has world wide distribution; Blumer (1967) distinguished 13 formae speciales based on a single species or a single section of a genus. A biologic form on Safflower was named as E. cichoracearum f.sp. carthami by Milovtzova (1937), while wild and cultivated lettuce appear to be attacked by separate strains (Schnathorst et al., 1958).

McKeen et al. (1966) studied the pathogenicity of Erysiphe cichoracearum on Helianthus annuus and examined the infected leaves under electron microscope and concluded that the haustoria of the fungus were elongated, ellipsoidal with twisted branches and were bathed in a cavity surrounding by the plasma membrane of the host. Further observation was made by McKeen and Bhattacharya (1968) as the changes in the constituents of the host cell wall

surrounding the infection peg of powdery mildew fungi, as the leaves infected with E. cichoracearum stained intensely with azure dye, methylene blue and cotton blue.

The Brownian movement has been observed in conidia of E. cichoracearum from H. annuus (Yarwood, 1978).

2.3. HOST RANGES AND HOST SPECIALIZATIONS: Powdery mildew fungi have wide host range, Salmon (1900) in his "Monograph of Erysiphaceae" listed about 1500 species as the hosts of powdery mildews. Weiss (1950) observed powdery mildews on 1340 hosts, out of 3100 host species, , shown in U.S.D.A. index of plant diseases. Blumer (1967) observed powdery mildews on 1928 plant species belonging to different families of Angiosperms. Hirata (1986) mentioned the host plants of powdery mildew fungi and listed 9838 Angiosperm species dispersed in 44 orders, 169 families and 1617 genera. Neither Gymnosperms, nor Pteridophytes are included. The total Angiosperm species being about 220,000 in number, as calculated from A. Engler's syllabus der Pflanzenfamilien, 12^{th} edition, 1967, the total host species correspond to about 4.5 percent of them.

The host species are divided into 9176 dicotyledons and occupying 93 percent of the total, while 662 plants of monocotyledons. Among 662, 634 are members of Gramineae and 28 are dispersed among seven other families.

There are several families having no host plants e.g. Aizoaceae, Theaceae and Melastomataceae. Some families having only one or a few host species e.g. Nyctaginaceae, Portulacaceae, Piperaceae, Polygalaceae and Myrsinaceae. On the other hand, families having many or at least several dozens of host species are also not rare. The following 19 families have more than hundred host species. Gramineae, Salicaceae, Betulaceae, Fagaceae, Polygonaceae, Ranunculaceae, Cruciferae, Saxifragaceae, Labiatae, Solanaceae, Rosaceae, Leguminosae, Euphorbiaceae, Umbelliferae, Ericaceae, Boraginaceae, Scrophulariaceae, Caprifoliaceae and Compositae. Among them Gramineae, Rosaceae, Leguminosae and Compositae have particularly large numbers of host species, as 634, 694, 1022 and 1708 respectively.

Powdery mildew fungi have been reported on different members of the Compositae. Blumer (1933) observed S. fuliginea on Adenostyles alliariae, Arnica montana, Bidens cernuns, B. melanocarpus, B. tripartitus, Bellidiastrum michelii, Calendula officinalis, Crepis paludosa, C. blattaroides, Erigeron acer, E. candensa, Helianthemum canum, H. bulgare, H. grandiforum, Leontodem hispida and Taraxacum officinalis (Compositae).

Pertaining to the finding of perfect stages, Neger (1923) reported S. fuliginea on Epilobium montanum (Onagraceae) and Taraxacum officinalis (Compositae). Groter and Eicker (1983) reported that the teleomorphic state of E. cichoracearum is newly recorded from South Africa on Zinnia sp. and Dahlia sp. The

deviating insertion of its appendages led to its identification as a new variety of E. cichoracearum as transvalensis. Perithecia of E. pisi on Sesbenia punica and S. xanthi from Bidens formosa were also found. Perithecia of E. cichoracearum on lactuca sp. reported by Labeda and Buizkowski (1986).

In India several workers have been observed the perfect stages viz. S. fuliginea on H. annuus (Patil, 1964; Patwardhan, 1965) from Maharashtra and Prasad et al. (1968) from Rajasthan; on Dimorphotheca sinuata by Mathur et al. (1971) from Rajasthan; on Bidens biternata (Khan et al., 1975); on Anaphalis contorta (Srivastava and Rawat, 1982) from Pauri (Garhwal). Paul and Kapoor (1985) observed the perithecia of Leviellula taurica on Senecio chrysanthemoides from Harwan, Kashmir.

In 1939, Rud described the life cycle of S. fuliginea (attacked on C. officinalis). Moore (1947) reported S. fuliginea on Doronicum sp.; Cineraria sp. has attacked by S. fusca (Ciocan, 1963); Marigold by S. fuliginea (Akhundov and Ulyanishchev, 1963). According to Capetti and Gabriela (1976) S. fuliginea on five spp. of Calendula; Oidium spp. on ten new hosts belonging to various genera including Hiracium, Campanula, Hyoscyanus. S. fuliginea f.sp. cyclachaenae found on Cyclachaena xanthifolia (Gelyuta, 1979). Hou and Lee (1979) observed S. fuliginea on Dahlia pinnata rather than E. cichoracearum. Reid and Dare (1986) reported S. xanthii on Chamomilla suaveolens from Britain; whereas, Tanaka et al. (1987) recorded new report of S. fuliginea on C. tinctorius

Ialongo (1987) mentioned S. fuliginea on Gerbera sp. Hirata (1966) reported that Sunflower had been infected with S. fuliginea in China, France, Japan, Holland, Italy, Yugoslavia and Switzerland.

E. cichoracearum has been reported on various hosts viz. Cineraria sp. (Mac Donald, 1939); Zinnia sp. (Baker and Locke, 1946) from California; Middleton (1971) reported it on Sunflower from South Queensland; Eliade (1975) from Romania reported on Z. elegans and Achillea coaractata; on Aneroba lipii by Khan and Ahmad (1979) from Jamahiriya (Libya), whereas, in 1980 Khan reported this pathogen on Hedypnosis cretica, Conyza bonasiensis and Sonchus oleraceous. Yukihiko (1980) observed on Chrysanthemum boreale; Helianthus tuberosus was infected with this fungus in Italy reported by Lorenzini and Triolo (1981) and Ialongo (1981) in Georgia, U.S.A.; Crute and Burns (1984) from U.S.A.; Dhanvantari and Jarvis (1985) from Canada; Klemm (1986) from Merat (J.D.R.) and Lebeda (1986) from Czeckoslovakia reported on Lactuca sativa. Milovtzova (1938) reported E. cichoracearum f.sp. carthami on Carthamus tinctorius, whereas, E. cichoracearum f.sp. helianthii on Sunflower was reported by Shopov (1976) from Bulgaria.

Eshed (1977) observed the Oidium type mildews from Bellis perennis, Chrysanthemum coronarium, while Oidiopsis type reported from Gerbera jamesonivi. Recently Koike et al. (1988) reported the Gazania as the host of Oidiopsis taurica.

Helyuta and Marchenko (1985) reported Uncinula bicornis on Aesculus hippocastamum from U.S.S.R., its origin and drawings are available.

In India, the Sunflower has been recorded as the host of S. fuliginea by Jhooty (1965) from Chandigarh. However, Srivastava and Rawat (1982) observed on Anaphalis contorta from Garhwal Himalayas.

The pathogen E. cichoracearum has been reported on H. annuus (Patel et al. 1949; Pavgi and Upadhyay, 1966); on Carthamus tinctorius (Saluja and Bhide, 1962). On sweet sultan (Centaurea moschata) and Acroclinium sp. (Helipterum roserum and H. album) by Jain and Singh (1968); on Inula recemosa by Narain and Saksena (1975), and recently reported by Perwez and Akram (1987) on Vernonia cinerea from Aligarh.

In 1982, Paul and Munjal reported E. artemisiae on Artemisia scopana; S. fuliginea on Erigeron bonariensis.

Bhatnagar and Kothari (1966) first time reported Oidium xanthami on Xanthium strumarium.

The Tridax procumbens has been recorded as the host of Leveillula taurica by Mathur et al. (1971).

Oidium spp. of the pathogen have also been reported on Galinsoga parviflora and Coreopsis sp. from Solan by Paul and Munjal (1982); on Gamolepis tagetes (Perwez and Akram, 1989) from Aligarh.

Reed (1908) observed that the Cucumber isolates of Erysiphe cichoracearum infects Sunflower while the isolates from Sunflower infects Cucumber and Squash poorly. Miller and Barret (1931) on the other hand, observed that forms on Cucumber and Sunflower did not cross infect each other. Schmitt (1955), while confirming these findings observed that Zinnia strains of E. cichoracearum had a wider host range than the forms of Inula spp., Helianthus spp., Cerianthe spp., Phlox or Cucurbits. He further reported that Zinnia isolate attack Z. elegans, Z. panciflora, Z. verticullata, H. annuus, Arctium minus, A. memorsum, Xanthium chinense, X. spiriosum, X. strumarium, Mikania scandens, Hieracium alpinum, H. prehanthoides, Inula helenium, Carlina acantis, Lactuca perennis, Cosmos spp., Scorzonera hispenica and Felicia amelloides of Compositae, Salkinglossia sinulata and Cerianthic major of Solanaceae and Boraginaceae respectively. The isolates from Phlox sp. were restricted to P. drummendi and cultivated perennial Phlox sp. The cucurbit isolates infect only members of Cucurbitaceae, but failed to develop on other non-cucurbits.

According to Schnathorst et al. (1958) Calendula isolate of E. cichoracearum was pathogenic on Calendula officinalis and Silybum marianum, while Lactuca sativa isolate on C. officinalis, L. sativa, L. serriola, S. marianum and Z. elegans. isolates from L. serriola, Salinus sp. and Z. elegans infect L. serriola, Salinus sp. and Z. elegans. While that from California, infect L. serriola and S. marianum. Therefore, the isolates of Erysiphe cichoracearum from different hosts and different localities, from

the same host differed in their host range, they also reported that Lactuca isolates of E. cichoracearum infect both potted and detached leaves of Calendula officinalis var. double mixed, Dahlia variabilis var. unwins dwarf-hybrids, H. angustifolia, H. annuus, L. serriola, Silybum marianum, Senecio cruentus, Z. elegans vars. floredoles scarlet, giant fantary and Delphinium hybridum var. giant imperial blue shade.

According to Hasan (1974), plant species comprising a number of cichoraceous plants closely related to Chondrilla and cultivated plants belonging to twenty three families particularly the cultivated Compositae, Cucurbitaceae, Solanaceae and Leguminosae, on which E. cichoracearum have been recorded, were inoculated with conidia of the powdery mildew. Moreover, three cultivars of all cultivated species recorded as hosts of any form of E. cichoracearum were tested. The E. cichoracearum from Chondrilla juncea did not develop on any of these plants. However, Yukihiko (1975) reported that the isolates of E. cichoracearum from Artemisia vulgaris var. indica maxima can not parasitize A. japonica, whereas, the isolates of S. fuliginea from Impatiens balsomina infects H. annuus. Morgan Jones (1975) observed a new species of powdery mildew i.e. Microsphaeropsis centaurea from Centaurea diffusa and its isolate was tested to C. diffusa and C. maculosa, both were infected with this pathogen. The fungus, E. cichoracearum was isolated from Sonchus oleraceus growing wild in Rome was pathogenic only to Sonchus spp. on

inoculating detached leaves of a wide range of plants (Ialongo, 1980). Mitov and Popov (1979) from Bulgaria reported that the isolate of E. cichoracearum f.sp. helianthii from Sunflower infects Jerusalum artichoke (H. tuberosus) and H. scaberimus and those isolate from H. tuberosus infect Sunflower under Bulgarian conditions. According to Chandra et al. (1981), S. fuliginea from Zinnia elegans, Erysiphe sp. from X. strumarium and E. cichoracearum from Coccinia cordifolia and E. pisi from Pisum sativum, only positive results were obtained with isolates from Z. elegans. Out of twenty varieties of different beans tested all the varieties except lobia beans vars. yard long cholai beans, improved black seeded, imporved red seeded, black seeded (IGFRI) and red seeded (IGFRI) were found susceptible to varying degree. The isolates of E. cichoracearum from Lettuce were inoculated onto the L. serriola and L. virosa among these two the later showed least infection, whereas, the former developed mild infection (Lebeda, 1986). Perwez and Akram (1988) reported that amongst Acroclinium sp., Aster sp., Bellis perennis, Cosmea sp., Calendula officinalis, Chrysanthemum carinatum, Cineraria sp., Dahlia variabilis, Dimorphotheca sinuata, Brachycome iberidifolia, Gaillardia sp., Gamolepis tagetes, H. annuus, Tagetes erecta, Lactuca sativa, Zinnia elegans, Eclipta alba, Sonchus sp., Xanthium strumarium and Tridax procumbens, only respective host was infected with S. fuliginea isolate from D. sinuata, while E. cichoracearum isolate from H. annuus failed to develop disease

except the respective host, on other hand, same pathogen from D. variabilis gave positive response on to the Cineraria sp., Lactuca sp., in addition to the respective host. E. cichoracearum, observed on Chenopodium ambrosoides and Z. elegans, caused infection on their respective hosts and failed to infect Benincasa hispida, Citrullus lanatus, C. vulgaris var. fistulosus, Cucumis melo, C. melo var. utilissimus, Luffa cylindrica, Momordica charantia, Coccinia cordifolia, Cucumis anguria, Luffa graveolans, Mukia maderaspatana, Abelmoschus esculentus, Calendula sp., Chrysanthemum sp., Cosmos sp., and Nicotiana tabacum (Akram and Perwez, 1989).

2.4. ENVIRONMENT AND POWDERY MILDEWS: The effect of different environmental factors on powdery mildews have been extensively studied by Graf Marin (1934), Cherewick (1944), Yarwood (1957) and Schnathorst (1965). Yarwood (1957) and Schnathorst (1965) reviewed the environmental factors on powdery mildew diseases. It was claimed that the development of powdery mildew in general was favoured by warm humid weather (Anonymous, 1946 & 1950); Steiner (1908) and Tucker (1852) reported that green house conditions were conducive as against out doorconditions and also hot dry weather (Wager, 1937). Out of the various environmental factors, temperature and relative humidity have been reported to have a profound effect on powdery mildew development.

The cardinal temperature for germination of conidia of different strains of E. cichoracearum ranged between 5-33°C (Levykh, 1940; Deslandes, 1954; Rossouw, 1959; Schnathorst, 1960; Morrison, 1961 & 1964 and Tafradzhiiski, 1963); for infection and growth of the powdery mildew ranged between 5-33°C (Levykh, 1940; Deslandes, 1954; Minev, 1957; Rossouw, 1957 & 1959 and Schnathrost, 1960). Conidial germination of E. cichoracearum from lettuce was highest at 18°C (Schnathorst, 1960). The cardinal temperature for infection of powdery mildew was 6-10°C (Minimum), 18°C (Optimum) and 27°C (Maximum).

Another important environmental factor is moisture which influence the germination of conidia, infection and growth of powdery mildews, formation and maturation of Perithecia.

Heavy infection of E. cichoracearum on Tobacco has been observed in field at high water level, reported by D'Angremond (1924). Corner (1935) observed that the conidia of E. graminis, Podosphaera leucotricha, Sphaerotheca pannosa and E. cichoracearum succumbed when remained in water for 1-3 hours; however, floating conidia germinated readily after 24 hours and produced upright germ tubes.

Related to the environmental factors, the more controversial aspect is relative humidity. It also plays an important role for the germination of conidia. Hashioka (1937) found that conidia of S. fuliginea from Cucumber germinated between 15-85 percent relative humidity. The survival of conidia was 14 days at

76-80 percent relative humidity, for 24 days at 93-98 percent relative humidity and for 38 days in a saturated atmosphere. Tafradzhiiski (1963) reported that conidia of the same host of S. fuliginea germinated best at 94 percent relative humidity but they failed to germinate in drops of water.

According to Levykh (1940), there was no development of symptoms when Tobacco plants inoculated with E. cichoracearum exposed to 10 percent relative humidity at 18-19°C. However, the typical symptoms appeared at 70-76 percent relative humidity. Deslandes (1954) observed 85 percent relative humidity was optimum for infection and sporulations in powdery mildew pathogens Minev (1957), Schnathorst (1960), Morrison (1961 & 1964) and Tafradzhiiski (1963) reported that the germination of E. cichoracearum from Tobacco occured slightly below the saturation. Optimum relative humidity ranged between 66-68 percent for Tobacco strains (Minev, 1957); 95.6-98.2 percent for lettuce strains (Schnathorst, 1960) and 94 percent for cucurbit strains (Tafradzhiiski, 1963). Germination of conidia was also observed in Calcium chloride chamber at 0.1 percent relative humidity by Morrison (1961 & 1964) and Schnathorst (1960). On the other hand, Rossouw (1959) reported the germination of conidia both at 0 percent and 100 percent relative humidity. Corner (1935), Minev (1957), Morrison (1961 & 1964) and Tafradzhiiski (1963) observed that the free water inhibited the germination of conidia, while Deslandes (1954) reported that the conidia of Lettuce strains of

E. cichoracearum were able to germinate in free water. Schnathorst (1960) observed that moisture stress gave highest germination of conidia of lettuce strains of E. cichoracearum. The development of powdery mildew was most affected by temperature but atmospheric humidity influenced the rapidity and severity of disease development. Highest germination of conidia of L. taurica from Cynara annuum was achieved at 100 percent relative humidity (Clark and Ayesuoffei, 1967). At low humidity, there was only a decline in germination but a reduction in mean germ tube length. Morrison (1964) observed that the free water on leaf-disc surface inhibited the germination of conidia of large number of powdery mildew fungi but high relative humidity favoured the germination. Nour (1958) studied the effect of different relative humidity on percentage germination of conidia of various powdery mildew fungi.

It had been claimed that both infection and incidence of powdery mildews were severe under dry conditions rather than wet climatic conditions (Wager, 1937; Anonymous, 1945; Boughey, 1949 and Palti, 1953). D'Angremond (1924), Blumer (1927), Doslandes (1954) and Morrison (1961) reported that high relative humidity favoured the incidence of powdery mildew. Brisley (1926), Beeley (1932), Moore (1936), Fisher (1938), Bremer (1940) and Parris (1949) were also of the opinion that overhead irrigation favoured the development of powdery mildew. Schnathorst (1959) reported that the growth of mycelium was abnormal, when a film of moisture was present on the surface of epidermis. Yarwood (1939), Schnathorst (1959) and Morrison (1961), on the other hand, reported that the film of free water did not favour the development of the

powdery mildews. An observation was made by Salmon (1903), Yossifovitch (1923) and Moseman et al. (1957), that the free water was essential for the maturation of ascospores. Disease epidemics on artichoke (H. tuberosus) was associated with limited rainfall and decreasing autumn temperature, cultivars which had almost entire leaf blades and no spines, were more resistant than those with lobate leaves (Ciccarone, 1953).

The conidia of powdery mildew fungi have been found to germinate at a wide range of pH but highest germination has been observed at pH 6.6-7.0 (Yarwood, 1957).

Childs (1940) observed a diurnal cycle of ascospores maturation in certain powdery mildew. Periodic microscopic examination of the Sunflower, Rose, Apple, Aster and Cucumber infected with E. cichoracearum revealed a more complex diurnal cycle of conidiophore development, abstriction occurred between 6-8 a.m. and then at 2-4 p.m. and formation of the succeeding crop of conidia occurred between 2-4 p.m. and 6-8 a.m. Highest abstriction of conidia of Sunflower powdery mildew occurred between 8.00 a.m. and 2.00 p.m.

The germination of conidia was also influenced by the time of collection. Yarwood (1936) reported that the highest germination of conidia of E. polygoni occurred when the spores were collected in the afternoon. Their germination however, decreased with onset of the darkness and the least germination was observed in early morning. Jhooty (1970), while confirming the above findings,

pointed out that such diurnal cycle was absent in S. fuliginea, S. macularis, E. graminis and E. cichoracearum. However, Yarwood (1936) suggested that regular alternation of light and dark periods may be responsible for expression of this phenomenon. Jhooty (1971) was of the view that alternation of light and dark periods may not be the basic cause of this phenomenon, but it certainly influenced the onset of low and high cycle in germination of conidia of E. polygoni.

Different environmental factors also influence the production of perithecia (Yarwood, 1957). Buchheim (1928) and Blumer (1948) reported that low relative humidity favoured the formation of perithecia. Similarly Bioletti (1907) reported that generally low temperature favoured the development of perithecia in powdery mildew. On the other hand, Cherewick (1944), Arya and Ghemawat (1953) reported that in E. graminis, formation of perithecia and ascospores was favoured at alternating moderate and low temperatures. Schnathorst (1959) reported that the formation and maturation of perithecia was also a matter of time rather than cyclic changes in temperature or alternate wetting and drying and he observed the formation of perithecia of E. cichoracearum at 23°C with 300 foot-candle illumination in leaf culture in 7 days. Perithecial development was also reported by Schnathorst (1959) at 13°C with 60 percent relative humidity and 900 foot-candle illumination. These observations led to conclude that the perithecia rarely developed in tropic. Bessey (1943), Ainsworth

(1950) and Yarwood (1957) reported that amongst the different climatic factors, temperature appeared to be more important for perithecial production. However, this is not true in India, a large number of perithecial development had been observed in powdery mildew fungi. Patwardhan (1965), while studying the effect of different factors affecting the development of perithecia on H. annuus, observed their development on large number of hosts during monsoon season.

An observation was made by Yarwood (1938) that the Sunflower plants grown in Hoagland solutions minus Boron were severely stunted and heavily mildewed, while plants grown with 1 and 10 ppm of Boron supplied as Boric acid made a normal growth and were much less mildewed.

Severity of mildew is directly related with plant vigour and that any soil or other factor which promote plant vigourity (Arnaud and Arnaud, 1931; Smith and Blair, 1950); Trelease and Trelease (1928) and Mansson (1955) found that low nitrogen and high potassium reduced the development of powdery mildew. Cole (1964 & 1966), on the other hand,reported that the plants grown in water culture fortified with all the elements were more susceptible to E. cichoracearum, than those grown in low potassium and nitrogen level. Laibach (1930) and Homma (1937) reported that low nutritive conditions of host favoured the development of perithecia.

Chapter 3

Materials & Methods

C H A P T E R - 3

MATERIALS AND METHODS

3.1. SURVEY: During the course of preliminary survey of composite growing localities at Aligarh and its adjoining areas, these were surveyed for the incidence and the severity of the powdery mildew diseases.

The severity of powdery mildew was graded as under:-

No infection (-)	=	No visible disease symptoms.
Mild infection (+)	=	Pustules few, small in size and scattered.
Moderate infection (++)	=	Pustules many, larger in size tending to coalesce.
Severe infection (+++)	=	Big pustules covering almost the entire leaf areas.

3.2. IDENTIFICATION OF THE CAUSAL ORGANISM: For the identity of the pathogen, infected plants were brought to the laboratory in the polythene bags.

In absence of the perithecia on the infected plants, the mycelial and conidial characters were taken into consideration for

the identification. These characters include, colour of the mycelium in older pustules (Rodigin, 1936; Yarwood, 1957); shape of conidia (Alcorn, 1968); conidial measurements (Bouwens, 1924 & 1927); presence and absence of fibrosin bodies (Homma, 1937; Clare, 1958 & 1964; Kable et al., 1963 and Jhooty, 1967) and type of germ tubes (Hirata, 1942 & 1955; Kable et al., 1963 and Zaracovitis, 1965).

For determining the size of conidia about 200 ± 50 conidia were measured from each of the infected composite plants and the range of size was calculated. For the observation of the presence or absence of the fibrosin bodies in conidia, as suggested by Kable and Ballantyne (1963), conidia were mounted in 3 percent aquous solution of potassium hydroxide (KOH).

For the study of the type of the germ tubes, conidia were dusted over dry clean glass slides placed on glass triangles in a petridish containing double distilled water at the bottom. Later, these were transferred in an incubator running at 15-30 °C. After 24 hours of incubation, conidia were stained in cotton blue and mounted in lactophenol for further observations.

Infected plants with perithecia were stored for the detailed study of characters, which help in ascertaining the identity of the pathogen. The perithecia were stained in cotton blue and mounted in lactophenol. On mechanical rupturing of the perithecia, the number of asci in each perithecium and ascospores per ascus were counted. The size of the perithecia, asci and

ascospores was also determined.

3.3. MAINTENANCE OF CULTURE OF POWDERY MILDEWS: For further studies of the pathogen, the inoculum should be maintained. For this, seedlings of the respective hosts in the cotyledonous stage or at 3-4 leaf stage, grown in autoclaved soil contained in 25 cm clay-pots, were inoculated. For inoculations, dry dusting technique was used throughout the studies as proposed by Yarwood (1957). The inoculated plants were kept in separate glass house chambers at 15-30°C in order to avoid mixing of inocula. The plants were regularly examined for the appearance and the development of disease.

3.4. HOST RANGE: To study the host range of twenty seven cultivated composites viz. Acroclinium sp. (Gray), Ageratum sp. (Linn.), Arctotis sp. (Linn.), Aster sp. (Torn ex. Linn.), Bellis perennis (Linn.), Brachycome iberidifolia (Benth.), Cacalia coccinea (Linn.), Calendula officinalis (Linn.), Carthamus tinctorious (Linn.), Centaurea moschata (Linn.), C. cyanus (Linn.), Chrysanthemum carinatum (Schousb), Cineraria sp. (Linn.), Coreopsis sp. (Linn.), Cosmos sulphonus = Cosmea sp. (Willd.), Dahlia variabilis (Desf.), Dimorphotheca sinuata (DC.), Gaillardia sp. (Fauger), Gamolepis tagetes (Less), Gazania splendens (Gaertin.), Helianthus annuus (Linn.), Helichrysum bracteatum (Vaill ex. Linn.), Lactuca sativa (Linn.), Tagetes erecta (Linn.), Tithonia sp. (Desf.ex Juss), Venidium sp. (Less), Zinnia elegans

(Facq.). Ten wild composites viz. Ageratum sp. (Linn.), Cirsium arvens (Scop.), Conyza japonica (Less), Eclipta alba (Hask.), Launaea sp. (Cass.), Pluchea sp. (Cass.), Sonchus oleraceous (Linn.), Tridax procumbens (Linn.), Vernonia cinerea (Less.) and Xanthium strumarium (Rafin.) and twenty-one non-composites viz. Abelmoschus esculentus (Medik), Benincasa hispida (Thumb.) Cogn, Cassia occidentalis (Linn.), Chenopodium ambrossoides (Linn.), C. album (Linn.), Coccinia cordifolia (Linn.), Cucurbita maxima (Duch ex Laun.), C. moschata (Poiret.), Gomphrena globosa (Linn.), Lagenaria leucantha (Dusch.) Rusby, Luffa acutangula (Linn.), L. cylindrica (Linn.), Lathyrus odoratus (Linn.), Lycopersecon esculentum (Mill.), Nicotiana tabacum (Linn.), Momordica charantia (Linn.), Viola tricolor (Linn.), Solanum nigrum (Linn.), S. melongena (Linn.), S. tuberosum (Linn.), Salvia sp. (Tourn.) and Trichosanthes anguina (Linn.), grown in 25 cm clay pots with autoclaved soil. These were inoculated with five composite isolates of Erysiphe cichoracearum obtained from Centaurea moschata, Cineraria sp., Dahlia variabilis, Vernonia cinerea and Zinnia elegans; seven of Sphaerotheca fuliginea from Acroclinium sp., Carthamus tinctorius, Chrysanthemum carinatum, Cosmos sulphonus, Dimorphotheca sinuata, Helianthus annuus and Xanthium strumarium and Oidium sp. from Bellis perennis, Brachycome iberidifolia and Gamolepis tagetes arbitrarily designated as Ec_1, Ec_2, Ec_3, Ec_4, Ec_5, Sf_1, Sf_2, Sf_3, Sf_4, Sf_5, Sf_6, Sf_7, O_1, O_2 and O_3 respectively.

Inoculated plants were kept in glas house as well as in the field. For field trials they were transferred with entire soil to the pits earlier dug at a distance of 8-12 ft. This was done to avoid injuries to the roots. Healthy seedlings were also transferred for control. Temperature in field ranged between 18-22°C at the time of tests. For each host-parasite combination there were five replicates. Uninoculated plants served as control. Inoculated plants were regularly examined, for the appearance of the disease. Observations were made after ten days of inoculation.

Host response has been categorised as under:-

Resistant (R) = Mildew failed to appear.

Susceptible (S) = Mildew appears.

3.5. VARIETAL SCREENING: One hundred and twelve varieties belonging to eighteen genera of the family Compositae were screened for varietal resistance. Varieties viz. Acroclinium sp. vars. special mixture (Sutton's seed), splendens mixed (Sutton's seed); Arctotis sp. vars. grandis hybrid (Sutton's seed), special hybrid (Sutton's seed); Aster sp. vars. california giants mixed (N. Cooper), powder puff mixed (N. Cooper), giant mixed (Punjab seed), local (Gaurav seed); Calendula officinalis vars. orange king (Sutton's seed), lemon queen (Sutton's seed), orange coronet (Sutton's seed), art shades (Sutton's seed), double mixed$_1$ (N. Cooper), fiesta gitana (Sutton's seed), double mixed$_2$(Punjab seed)

local (Gaurav seed); Carthamus tinctorius var. kinko (Sutton's seed); Chrysanthemum carinatum vars. coronarium mixed (N. Cooper), fine mixed (Punjab seed), local (Gaurav seed); Cineraria sp. var. large single superb mixed (Sutton's seed); Cosmos sulphonus vars. alipore beauty (Sutton's seed), klondyke mixed (Sutton's seed), single mixed (Sutton's seed), double mixed (Sutton's seed), tall orange (N. Cooper), purity (N. Cooper), cosmos mixed (Punjab seed), pinkie (N. Cooper), double crosted mixed (N. Cooper), local (Gaurav seed); Coreopsis sp. vars. dwarf mixed (Sutton's seed), tall mixed (Sutton's seed), picta (Sutton's seed), grandiflora double (N. Cooper); Dahlia variabilis vars. double mixed (Punjab seed), unwins dwarf mixed (N. Cooper), large fld. mixed (N. Cooper), giant double mixed (Sutton's seed), cactus mixed (N. Cooper), local (Gaurav seed); Dimorphotheca sinuata vars. glistening white (Sutton's seed), special mixture (Sutton's seed), giant orange (Sutton's seed), mixed (Punjab seed); Gaillardia sp. vars. double mixed (N. Cooper), lorenziana single mixed (N. Cooper), lollypop yellow (Sutton's seed); Gazania splendens vars. sunshine hybrid mixed (Sutton's seed), hybrid mixed (Sutton's seed); Helianthus annuus vars. double chrysanthemum fld. (Sultan garden), sungold dwarf (N. Cooper), chrysanthemum fld. mixed (N. Cooper), sunburst (Sutton's seed), double orange (Sutton's seed), dwarf sungold (Sutton's seed), bronze hybrid (N. Cooper), double sungold (Punjab seed), japanees single maniature (Punjab seed), $local_1$ (Gaurav seed), $local_2$ (Sultan garden); Helichrysum bracteatum vars. large fld. mixed (Sutton's seed), double mixed

(Punjab seed), choice mixed (N. Cooper); Lactuca sativa vars. paris whitecos (N. Cooper), ice berg (N. Cooper), local (Punjab seed); Tagetes erecta vars. double mixed (Sultan garden), french petite mixed (Sutton's seed), giant double african mixed (Sutton's seed), giant double lemon (Sutton's seed), giant double orange (Sutton's seed), french red brocade (Sutton's seed), sunset giants mixed (Sutton's seed), cupid yellow (Poocha seed), dwarf harmony (Poocha seed), hybrid gee whiz lemon (Sutton's seed), tall african mixed (N. Cooper), french dwarf mixed (N. Cooper), crackerjack (N. Cooper), chrysanthemum fld. mixed (N. Cooper), local (Sultan garden) and Zinnia elegans vars. giant hybrid mixed (N. Cooper), dahlia fld. polar bear (N. Cooper), dahlia fld. scarlet flame (N. Cooper), dahlia fld. purple prince (N. Cooper), elegans choice mixed (N. Cooper), dahlia fld. mixed envy, green (Poocha seed), giant dahlia fld. mixed (Sultan garden), dahlia fld. royal purple (Poocha seed), dahlia fld. golden state (Poocha seed), giant dahlia illumination (Poocha seed), dahlia fld. golden dawn (N. Cooper), dahlia fld. crimson monarch (N. Cooper), dahlia fld. dream (N. Cooper), equisite (N. Cooper), dahlia fld. oriole (N. Cooper), california giant mixed (N. Cooper), lilliput mixed (N. Cooper), rich salmon rose (Sutton's seed), giant double yellow (Sutton's seed), giant double orange (Sutton's seed), persian carpet (N. Cooper), linearis orange (N. Cooper), haageana hybrid (Sutton's seed), scarlet red (Punjab seed), lilliput (Punjab seed), golden yellow (Punjab seed), double yellow (Gaurav seed),

white (Punjab seed), giant double white (Sutton's seed), dahlia fld. mixed (N. Cooper), were grown in 25 cm clay pots. These were inoculated with different isolates of E. cichoracearum from C. moschata, Cineraria sp., D. variabilis, V. cinerea and Z. elegans (Composites) and from Coccinea cordifolia (Ec_6) and Benincasa hispida (Ec_7) (non-composites). Inoculated plants were transferred to glass house bench as well as in the field.

The above studies were also supplemented by observing the development of powdery mildew on detached leaves or leaf-discs (Morrison, 1961 & 1964).

Observations of disease intensity were made daily for two weeks or so after inoculations. The following numerical rating have been used throughout for disease intensity (Wheeler, 1969).

Grade	Discription	Infection rating
Highly resistant	Plants completely free from infection.	0
Resistant	Mycelium developing in small patches disappearing later or at best covering 1-25% leaf area.	1
Susceptible	Many small colonies appearing, later coalescing and covering 26-75% leaf area. Mycelium developing on stem as well.	2
Highly susceptible	Entire plant covered uniformly by mildew.	3

Throughout the studies the perithecial production was also examined if any, wherever they were produced, the time for the apperance of perithecia was also recorded. In case perithecia were produced they were mechanically ruptured and examined for number of asci and ascopores.

3.6. COMMON HOST TEST: Powdery mildew disease of composites seem to be caused by both Erysiphe cichoraccarum and Sphacrotheca fuliginea. For the test of common host, the seedlings of Helianthus annuus were raised in 25 cm clay-pots containing autoclaved soil. Plants of H. annuus were inoculated with conidia of E. cichoracearum and S. fuliginea obtained from Zinnia elegans and H. annuus respectively, to find out whether the H. annuus is a common host.

Following sets were made to certify the host specificity of H. annuus:-

(1) Plants were inoculated only with E. cichoracearum.

(2) Plants were inoculated exclusively with S. fuliginea.

(3) E. cichoracearum and S. fuliginea both inoculated on different leaves of the same plant.

(4) Half portion of a leaf inoculated with E. cichoracearum and another half with S. fuliginea.

(5) Uninoculated plants served as control.

All the sets were kept on separate glass house benches, (temperature ranged 22-25°C). Observations were made after three days of inoculations, for the appearance of powdery mildew disease and also examined regularly for the formation of perithecia, if any.

3.7. GERMINATION OF CONIDIA: To study the effect of temperature and relative humidity pertaining to the germination of conidia, it is catagorised under the following headings:-

(1) Effect of temperature:- To determine the effect of temperature on conidial germination, freshly formed conidia were dusted over a dry clean glass slide and kept in incubation chamber. The assembly from the incubation chamber was transferred to incubators each running at -5, 5, 10, 15, 20, 25 and 30°C. After 8, 12, 24, 36, 48, 60 and 72 hours of incubation, slides were examined for germination of conidia and percentage of germination was also taken.

(2) Effect of relative humidity:- Super saturated solutions of the following salts were prepared to maintain the different relative humidities (Hand book of Chemistry and Physics, 1957).

The super saturated solutions were transferred to lower chambers of small dessicator which would serve as humidity chambers. Freshly developed conidia almost of the same size, age were uniformly dusted over the clean cover glass with the help of glass rod (Nair, Sadasivan and Ellingboe, 1962). The entire

assembly was kept as 20°C; after 8, 12, 24, 36, 48, 60 and 72 hours of incubation, the number of conidia that had germinated and those failed to germinate were counted and the percentage germination of conidia was also be noted.

Super saturated solutions of	Relative humidity (%) at 20°C
Sodium nitrate	66
Sodium acetate	78
Ammonium sulphate	81
Zinc sulphate	90
Sodium hydrogen phosphate	95
Double distilled water	100

For studying the effect of temperature and relative humidity on disease development, surface sterilized seeds of susceptible varieties were grown in autoclaved soil contained in 25 cm clay pots. The plants in cotyledonous stage were inoculated with conidia obtained from the original culture, maintained in glass house. These were transferred to growth chambers, kept at different temperatures viz. 5, 10, 15, 20, 25 and 30°C with 66, 81 and 90 percent relative humidities respectively.

At each combination of temperature and relative humidity, the plants were regularly examined for the appearance of the disease

and perithecia.

3.8. EFFECT OF DIFFERENT TEMPERATURES ON THE DEVELOPMENT OF POWDERY MILDEW ON DETACHED LEAVES AT THREE DIFFERENT RELATIVE HUMIDITIES: To see the effect of different temperatures viz. 5, 10, 20 and 25°C at 95 percent relative humidity as well as 81, 90 and 95 percent relative humidities at 20°C, on the development of powdery mildew on detached leaves of lilliput, golden yellow and haageana hybrid of Zinnia elegans were taken.

For this purpose plastic petriplates were taken, then in the centre of the petriplates a hole of 5 mm was made, through which petiole of the test variety could passed. Through this hole a glass tube was fixed with the help of paraffin wax. In the petriplates supper saturated solution of the chemicals (listed on page 38) was kept for desired relative humidities at 20°C. Each petriplate contain super saturated solution of one chemical.

The petriplate was made air tight and placed over a beaker containing water. Detached leaves were placed inside the petriplates over the glass slides. Detached leaves were inoculated with conidia of E. cichoracearum obtained from Z. elegans by dry dusting. The petiole of the leaf was passed through the glass tube to be dipped in water. Three replicates of each set was kept at 5, 10, 15, 20 and 25°C temperature at 95 percent relative humidity and 81, 90 and 95 percent relative humidity at 20°C.

Observations were made regularly after 4 days of inoculation for the appearance of the disease.

3.9. ASCOSPORE GERMINATION: Leaves and stem of C. carinatum and H. annuus with perithecia of S. fuliginea were either:-

(1) kept in small terylene bags and burried in the soil.

(2) transferred in plastic tubes stored at -5, 5, 10, 15, 20, 25 and 30°C for 220 days.

From each treatment plant material having perithecia was fixed to the inner portion of the humidity chamber, the base of which either had slides on glass triangle or the floating leaves of composites of the base, as suggested by Schnathorst, 1959.

The whole assembly was transferred to the temperature cabinates running at seven different temperatures and six combinations of temperatures.

Chapter 4

Experimental Results

C H A P T E R - 4

EXPERIMENTAL RESULTS

4.1. SURVEY: A survey was made to determine the incidence and severity of powdery mildew on different members of compositae in different localities at Aligarh and its adjoining areas. Results presented in Tables 1 & 2 (Fig. 1) indicates that different cultivated composites viz. Acroclinium sp., Bellis perennis, Brachycome iberidifolia, Carthamus tinctorius, Centaurea moschata, Chrysanthemum carinatum, Cineraria sp., Cosmos sulphonus, Dahlia variabilis, Dimorphotheca sinuata, Gamolepis tagetes, Gazania splendens, Helianthus annuus, Zinnia elegans and three wild composites viz. Ageratum conyzoides, Vernonia cinerea and Xanthium strumarium were found to be attacked with powdery mildew to a varying degree under field conditions.

The detailed results of survey are given below:-

Table - 1:- Comprising University campus, Fort area and Dodhpur area.

UNIVERSITY CAMPUS: During January to April, severe infection was observed on Acroclinium sp., C. tinctorius, C. carinatum, Cosmos sulphonus, D. variabilis, D. sinuata, H. annuus, Z. elegans and X. strumarium. Moderate infection on B. iberidifolia, G. tagetes while a mild infection was observed on B. perennis, V. cinerea,

TABLE - 1:- Incidence and severity of powdery mildews on the members of compositae in different localities at Aligarh and its adjoining areas during January to April, May to August and September to December.

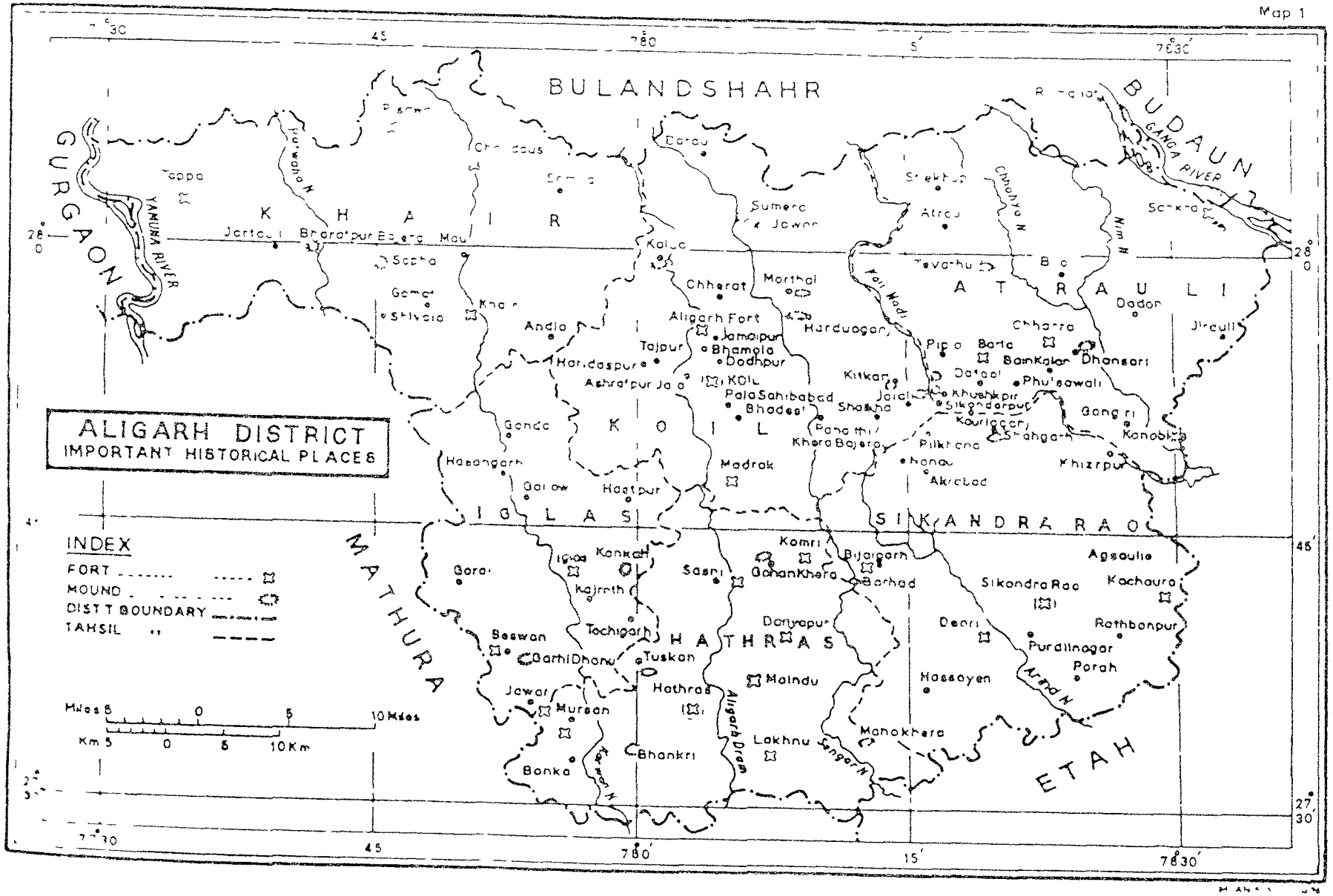
HOSTS	UNIVERSITY CAMPUS			FORT AREA			DODHPUR AREA		
	JAN-APR	MAY-AUG	SEP-DEC	JAN-APR	MAY-AUG	SEP-DEC	JAN-APR	MAY-AUG	SEP-DEC
Acroclinium sp.	+++	Ab	+	Ab	Ab	Ab	Ab	Ab	Ab
Ageratum conyzoides	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Bellis perennis	+	Ab	-	Ab	Ab	Ab	Ab	Ab	Ab
Brachycome iberidifolia	++	Ab	-	Ab	Ab	Ab	Ab	Ab	Ab
Carthamus tinctorius	+++	Ab	-	Ab	Ab	Ab	Ab	Ab	Ab
Centaurea moschata	Ab	-	-	Ab	Ab	Ab	Ab	Ab	-
Chrysanthemum carinatum	+++	-	+	+++	-	-	-	-	-
Cineraria sp.	+	-	-	++	Ab	-	-	-	-
Cosmos sulphonus	+++	Ab	++	++	Ab	-	++	Ab	+
Dahlia variabilis	+++	-	+	++	Ab	-	+	Ab	+
Dimorphotheca sinuata	+++	Ab	+	Ab	Ab	Ab	Ab	Ab	Ab
Gamolepis tagetes	++	Ab	-	Ab	Ab	Ab	Ab	Ab	Ab
Gazania splendens	+	Ab	-	Ab	Ab	Ab	Ab	Ab	Ab
Helianthus annuus	+++	-	-	+++	-	+	++	-	+
Vernonia cinerea	+	-	+	-	-	-	-	-	-
Xanthium strumarium	+++	-	++	+++	-	++	+++	-	++
Zinnia elegans	+++	-	+	+++	-	+	++	-	+

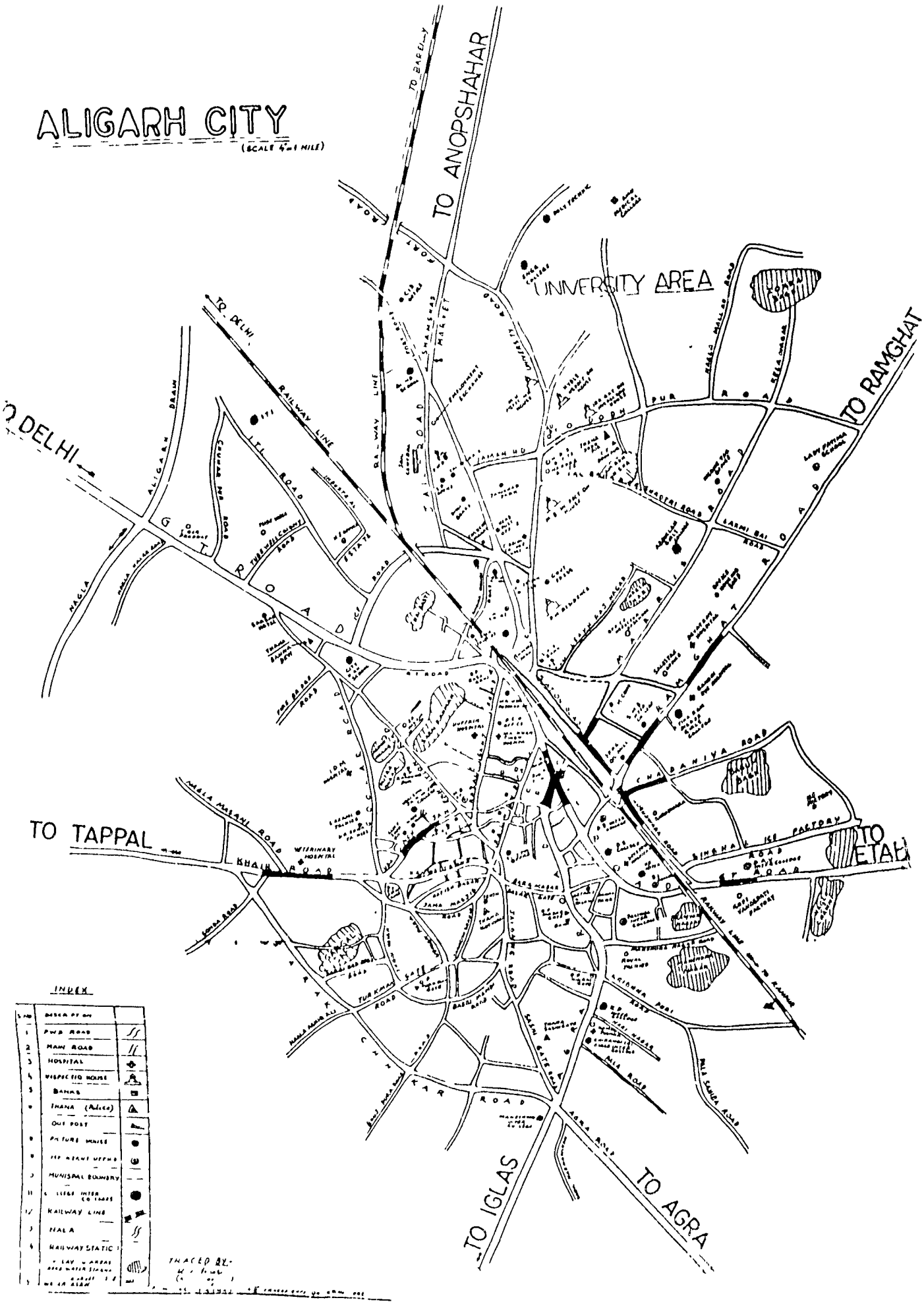
+++ = severe infection; ++ = moderate infection; + = mild infection; - = no infection;
Ab = plants are not grown.

Fig. 1: Severity of the powdery mildew; - = No infection;
+ = Mild infection; ++ = Moderate infection;
+++ = Severe infection.

Fig.1

Map 1


BULANDSHAHR
GURGAON
YAMUNA RIVER
K H A I R
BUDAUN
GANGA RIVER
A T R A U L I
K O I L
I G L A S
SIKANDRA RAO
MATHURA
H A T H R A S
ETAH
ALIGARH DISTRICT
IMPORTANT HISTORICAL PLACES
INDEX
FORT
MOUND
DIST T BOUNDARY
TAHSIL
Miles 5 0 5 10 Miles
Km 5 0 5 10 Km
Jartoli
Bharatpur Bajeng
Mau
Sasni
Kol
Chharat
Morthal
Aligarh Fort
Jamalpur
Bhamola
Dodhpur
Harduagan
Andio
Tajpur
Haridaspur
Ashrafpur Jat
Pala Sahibabad
Bhadesi
Shakha
Kitkari
Jalali
Khushkpur
Sikandarpur
Kaurigarh
Shahgarh
Pilkhana
Akrabad
Khizrpur
Gangri
Kanoble
Dadon
Jirauli
Chhatra
Bamkalan
Dhansari
Phulsawali
Pipra
Barla
Dalgal
Gonda
Hasangarh
Garaw
Hastpur
Madrak
Khera Bajeray
Panathi
Komri
Bijaigarh
Barhad
Gohankhera
Agsaulia
Kachaura
Sikandra Rao
Rathbanpur
Purdilnagar
Porah
Deori
Dariyapur
Malndu
Hathras
Lakhnu
Manokhera
Hassayen
Jawar
Mursan
Bankra
Banka
Sasni
Kajrath
Tochigarh
Tuskan
Garhi Dhanu
Beswan
Gorai
Kankarh
Iglas
Sonkh
Jalesar
Etah
Kasganj
Aligarh Drain
Nadan
Sengar N
Kanar N
Nim N
Kali Nadi
Chhoiya N
Patwai N
Sumera
Jawar
Atrauli
Sekhupur
Tappa
Chandous
Sarai
Shivala
Khair
Sonkh
Jalesar
Etah
Kasganj
28° 0
27° 30
45
7830'
15'
780'
5'
30'


ALIGARH CITY
(SCALE 4"=1 MILE)
TO ANOPSHAHAR
UNIVERSITY AREA
TO RAMGHAT
TO DELHI
TO TAPPAL
TO IGLAS
TO AGRA
INDEX

Cineraria sp. and G. splendens. However, during the scorching days of summer months (May & June) the available plants were free from the disease.

Again during September to December the disease appeared on the plants. Moderate infection was found only on C. sulphonus and X. strumarium; mild infection on Acroclinium sp., C. carinatum, D. variabilis, D. sinuata, V. cinerea and Z. elegans; on the other hand, B. perennis, B. iberidifolia, C. tinctorius, C. moschata, Cineraria sp., G. tagetes, G. splendens and H. annuus were remained free from the infection.

FORT AREA: During January to April, moderate infection was observed on Cineraria sp., C. sulphonus, D. variabilis and severe infection on C. carinatum, H. annuus, Z. elegans and X. strumarium while V. cinerea remained free from infection. Between the months of May to August, the growing composite plants were remained free from the attack of powdery mildews. During September to December, mild infection was noticed on H. annuus and Z. elegans; moderate infection on X. strumarium. Whereas C. carinatum, Cineraria sp., C. sulphonus, D. variabilis and V. cinerea were free from the disease.

DODHPUR AREA: From January to April, severe infection was found on X. strumarium; moderate on C. sulphonus, H. annuus and Z. elegans; mild on D. variabilis and no infection on C. carinatum, Cineraria sp. and V. cinerea.

No infection was reported during May to August on available composites. X. strumarium was also found moderately infected during September to December, whereas, mild infection was observed on C. sulphonus, D. variabilis, H. annuus and Z. elegans. The plants viz. C. carinatum, Cineraria sp., C. moschata and V. cinerea were remained free from infection during the said period.

Table - 2:- Comprising Sasni (Agra Road), Gabhana (G.T. Road) and Narora.

SASNI (AGRA ROAD): During January to April, moderate infection was observed on C. carinatum, C. sulphonus, H. annuus and Z. elegans, whereas, a mild infection on D. variabilis and severe on X. strumarium. On the other hand, Cineraria sp. and V. cinerea were free from the disease.

Between May and August no powdery mildew was reported on the available plants.

During September and December moderate infection was recorded on C. sulphonus and X. strumarium, while C. carinatum, V. cinerea, Cineraria sp., D. variabilis, H. annuus and Z. elegans remained free from the disease.

GABHANA (G.T. ROAD): Between the month of January and April, severe infection was recorded on C. carinatum, C. sulphonus, D. variabilis and X. strumarium but on the other hand, moderate infection was observed on Cineraria sp. and H. annuus, whereas,

TABLE - 2:- Incidence and severity of powdery mildews on the members of compositae in different localities at Aligarh and its adjoining areas during January to April, May to August and September to December.

HOSTS	SASNI			GABHANA			NARORA		
	JAN-APR	MAY-AUG	SEP-DEC	JAN-APR	MAY-AUG	SEP-DEC	JAN-APR	MAY-AUG	SEP-DEC
Acroclinium sp.	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Ageratum conyzoides	Ab	Ab	Ab	+	-	++	Ab	Ab	Ab
Bellis perennis	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Brachycome iberidifolia	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Carthamus tinctorius	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Centaurea moschata	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Chrysanthemum carinatum	++	Ab	-	+++	Ab	-	-	Ab	-
Cineraria sp.	-	Ab	-	++	Ab	+	Ab	Ab	Ab
Cosmos sulphonus	++	Ab	++	+++	-	++	Ab	-	Ab
Dahlia variabilis	+	Ab	-	+++	Ab	+	-	Ab	-
Dimorphotheca sinuata	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Gamolepis tagetes	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Gazania splendens	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab	Ab
Helianthus annuus	++	-	-	++	-	++	-	-	-
Vernonia cinerea	-	-	-	-	-	-	-	-	-
Xanthium strumarium	+++	-	++	+++	-	++	-	-	++
Zinnia elegans	++	-	-	-	-	++	-	-	-

+++ = severe infection; ++ = moderate infection; + = mild infection; - = no infection;
Ab = plants are not grown.

mild infection on A. conyzoides; V. cinerea and Z. elegans were free from the disease.

This locality was again surveyed during the month of May to August, the available members of this family were free from the disease.

During the month of September to December a moderate infection was observed on C. sulphonus, H. annuus, Z. elegans, A. conyzoides and X. strumarium.

Cineraria sp. and D. variabilis showed mild intensity of the disease but C. carinatum and V. cinerea were free from disease.

NARORA: During the month of January to April the available composites viz. C. carinatum, D. variabilis, H. annuus, Z. elegans, V. cinerea and X. strumarium were healthy at this locality.

Occurrence of powdery mildew was not recorded on available composites during the hot-month, i.e. May to August.

The same locality was surveyed during the period of September to December, it was observed that X. strumarium was moderately infected. Whereas, the other members of Compositae viz. C. carinatum, D. variabilis, H. annuus, Z. elegans and V. cinerea were free from the disease.

4.2. IDENTITY OF THE CAUSAL ORGANISM: To ascertain the identity of the causal organism, it is clear from the Table - 3 that the

TABLE - 3:- Mycelial and conidial characters of powdery mildews obtained from seventeen composites.

HOSTS	COLOUR OF MYCELIUM	FIBROSIN BODIES	MEASUREMENT OF CONIDIA	SHAPE OF CONIDIA	STRUCTURE OF GERM TUBES
Acrolinium sp.	GW	FP	31.2-46.2 x 14.7-24.2 um	E	Bi
Ageratum conyzoides	GW	FP	24.0-35.0 x 16.1-23.8 um	E+C+R	SA
Bellis perennis	GW	FP	31.2-42.0 x 14.4-21.0 um	E+C+R	SA
Brachycome iberidifolia	GW	FA	28.0-59.5 x 14.0-24.1 um	E+C+R	SA
Carthamus tinctorius	GW	FP	28.7-52.5 x 17.5-23.8 um	E	Bi
Centaurea moschata	CW	FA	24.5-35.0 x 13.7-20.3 um	C	SA
Chrysanthemum carinatum	GW	FP	24.5-36.1 x 15.1-21.7 um	E	Bi
Cineraria sp.	CW	FA	26.3-38.5 x 15.1-20.7 um	C	SA
Cosmos sulphonus	GW	FP	21.0-58.8 x 13.3-23.1 um	E	Bi
Dahlia variabilis	CW	FA	28.0-45.9 x 14.4-23.1 um	C	SA
Dimorphotheca sinuata	GW	FP	32.2-59.2 x 16.8-21.4 um	E	Bi
Gamolepis tagetes	GW	FA	21.0-52.5 x 14.0-22.1 um	E+C+R	SA
Gazania splendens	GW	FA	28.0-41.7 x 13.7-22.9 um	E+C+R	SA
Helianthus annuus	GW	FP	30.5-48.3 x 15.8-24.9 um	E	Bi
Vernonia cinerea	CW	FA	24.5-39.2 x 15.1-20.3 um	C	SA
Xanthium strumarium	GW	FP	20.0-32.5 x 10.5-19.0 um	E	Bi
Zinnia elegans	CW	FA	26.3-42.7 x 14.0-28.0 um	C	SA

GW = grayish white; CW = cottony white; FP = fibrosin bodies present; FA = fibrosin bodies absent
E = elliptical; C = cylindrical; R = spherical; Bi = bifurcated germ tubes;
SA = single straight germ tubes with appressoria.

colour of the mycelium has cottony white, obtained from the older pustules of C. moschata, Cineraria sp., D. variabilis, V. cinerea and Z. elegans, while grayish white from the remaining collected infected plants.

The conidia obtained from C. moschata, Cineraria sp., D. variabilis (Figs. 2-4), V. cinerea and Z. elegans were cylindrical in shape (Fig. 5) and measuring 24.5-35.0 x 13.7-20.3 um; 26.3-38.5 x 15.1-20.7 um; 28.0-45.9 x 14.4-23.1 um; 24.5-39.2 x 15.1-20.3 um and 26.3-42.7 x 14.0-28.0 um respectively. Fibrosin bodies were absent in the conidia obtained from above cited hosts when mounted with 3 percent KOH aqueous solution. On germination the conidia produced straight germ tubes with appressoria (Fig. 5).

On the basis of these characters it can be concluded that the causal agent of the above hosts was Erysiphe cichoracearum.

The conidia of powdery mildew obtained from Acroclinium sp., C. tinctorius, C. carinatum, C. sulphonus, D. sinuata (Figs. 6-9) H. annuus and X. strumarium were elliptical in shape (Fig. 10) and measuring 31.2-46.2 x 14.7-24.2 um; 28.7-52.5 x 17.5-23.8 um; 24.5-36.1 x 15.1-21.7 um; 21.0-58.8 x 13.3-23.1 um; 32.2-59.2 x 16.8-21.4 um; 30.5-48.3 x 15.8-24.9 um and 20.0-32.5 x 10.5-19.0 um respectively.

When these conidia were mounted with 3 percent KOH aqueous solution, the fibrosin bodies were present under microscope. On

Fig. 2: Leaves of Centaurea moschata infected with powdery mildew.

Fig. 2

Fig. 3: Leaf of Cineraria sp. infected with powdery mildew.

Fig.3

Fig. 4: Leaves and flower of Dahlia variabilis infected with powdery mildew.

Fig. 4

Fig. 4: Stem of Dahlia variabilis infected with powdery mildew.

Fig. 4

Fig. 5: (a) Conidia of *Erysiphe cichoracearum* from *Dahlia variabilis*.

(b) Germ-tube (close-up).

Fig. 5 (a)

Fig. 5 (b)

Fig. 6: Leaf of Carthamus tinctorius infected with powdery mildew.

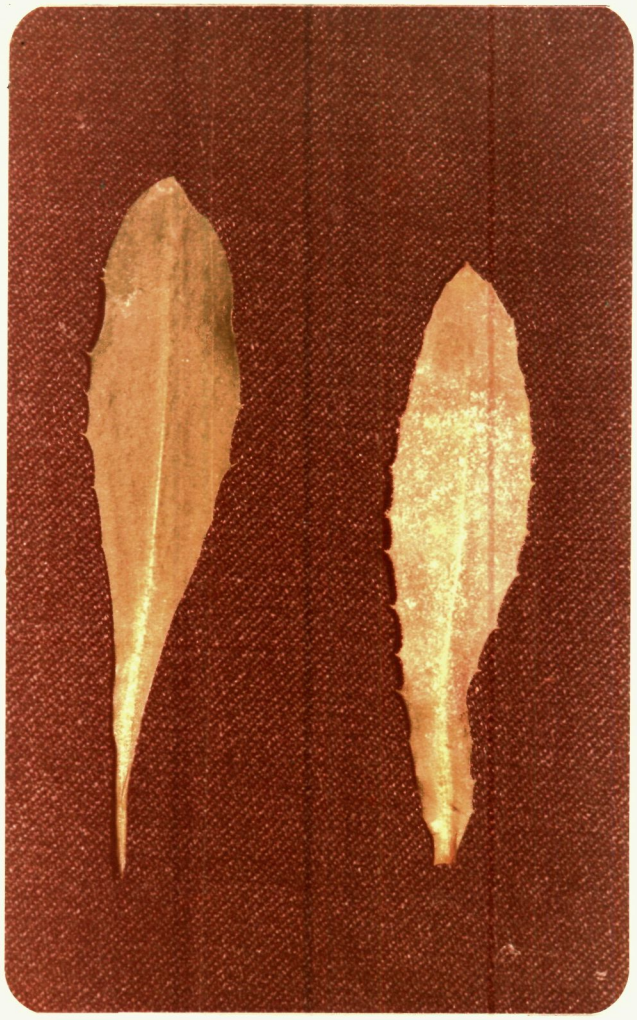


Fig. 6

Fig. 7: Chrysanthemum carinatum infected with powdery mildew.

Fig.7

Fig. 8: Cosmos sulphonus infected with powdery mildew.

Fig.8

Fig. 9: Leaves of Dimorphotheca sinuata infected with powdery mildew.

Fig·9

germination they produce bifurcated germtubes (Fig . 10).

Taking into consideration these characters, it can be concluded that these plants were the hosts of Sphaerotheca fuliginea.

A mixture of elliptical, cylindrical and spherical conidia obtained from the infected leaves of A. conyzoides, B. perennis, B. iberidifolia, G. tagetes and G. splendens and measuring 24.0-35.0 x 16.1-23.8 um; 31.2-42.0 x 14.4-21.0 um; 28.0-59.5 x 14.0-24.1 um; 21.0-52.5 x 14.0-22.1 um and 28.0-41.7 x 13.7-22.9 um respectively. Fibrosin bodies were present in A. conyzoides and B. perennis, whereas absent in B. iberidifolia, G. tagetes and G. splendens. On germination they produce straight germtubes with and without appressoria.

On the basis of these preliminary observations it can be concluded that conidia from these hosts do not confirm neither the characters of E. cichoracearum nor of S. fuliginea. Hence they were kept the category under Oidium spp.

The perithecia appeared in late March, 1989 on the living stem of H. annuus and living leaves of C. carinatum. They were dark brown in colour and spherical, having numerous basally inserted myceloid appendages. On mechanical rupturing, it reveals only one ascus in each perithecium. The shape of ascus was obovate to subglobose having 3-8 spherical ascospores (Figs. 11-15).

Fig. 10: (a) Conidia of *Sphaerotheca fuliginea* from *Carthamus tinctorius*.

(b) Showing fibrosin bodies.

(c) Close-up of fibrosin bodies.

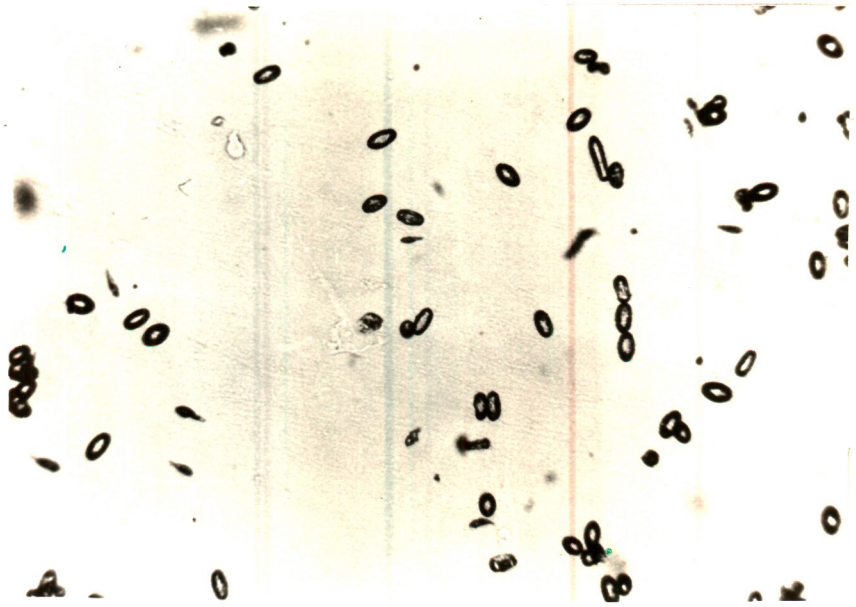


Fig. 10 (a)

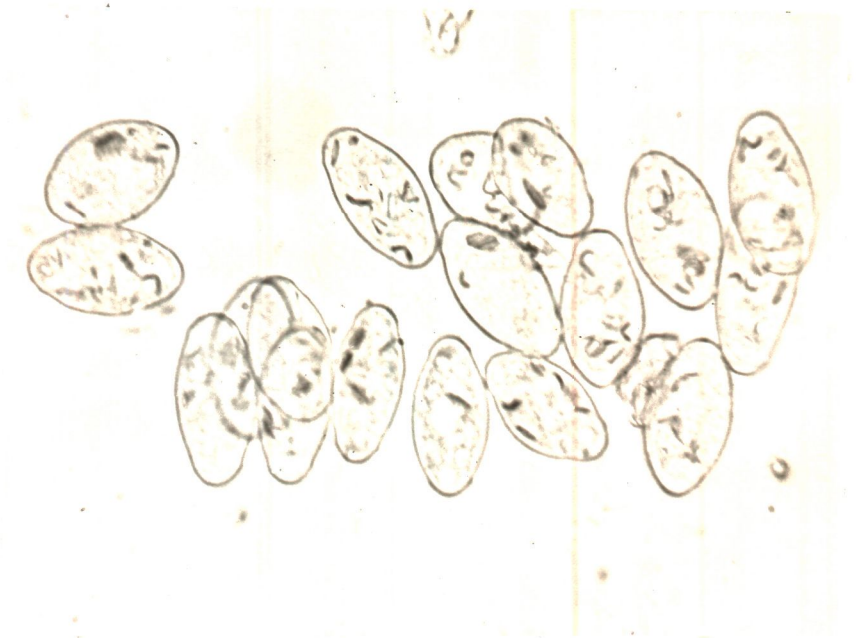


Fig. 10 (b)

Fig. 10: (d) Bifurcated germ tube of S. fuliginea from C. tinctorius.

Fig·10 (d)

Fig. 11: Stem of Helianthus annuus showing perithecia.

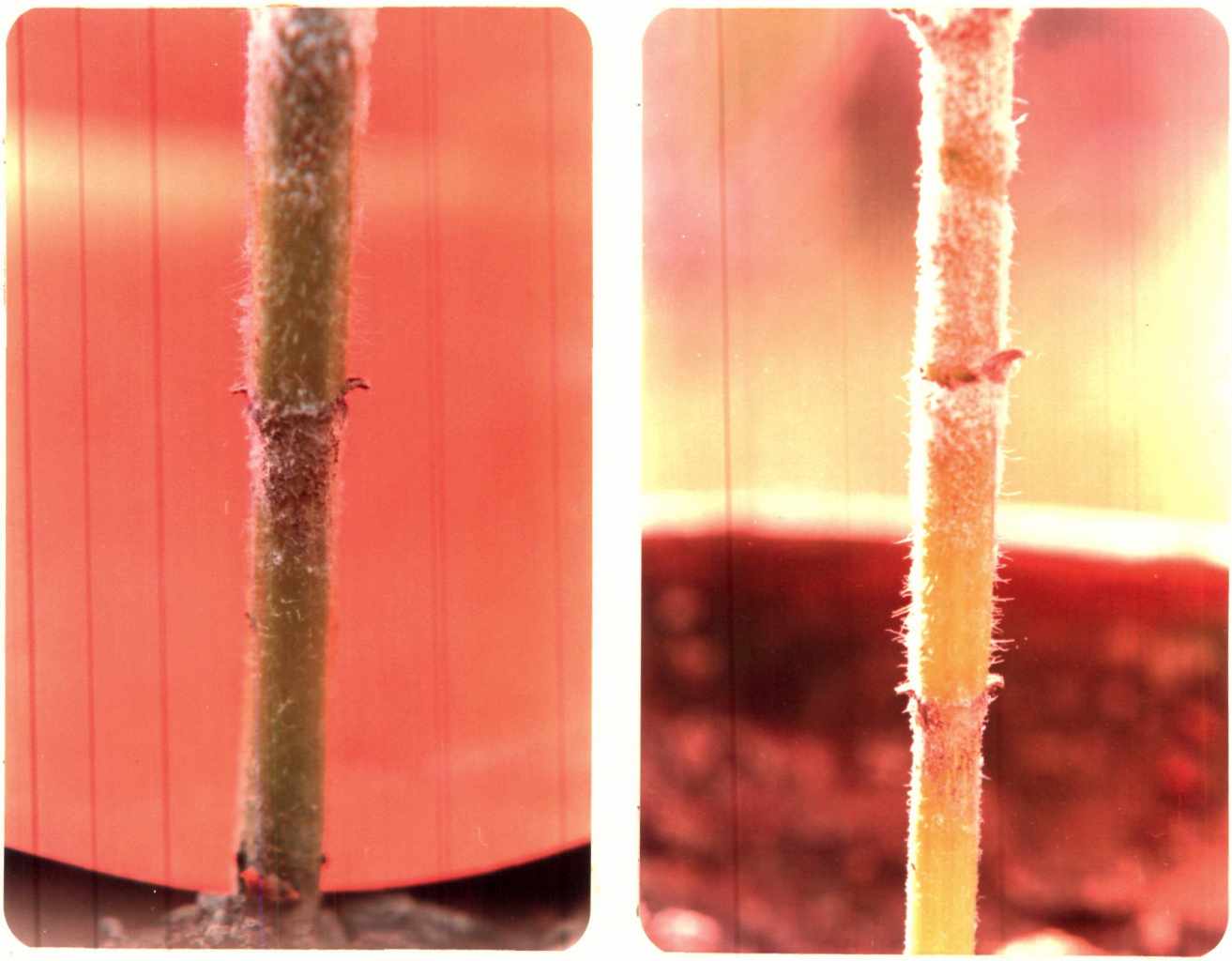
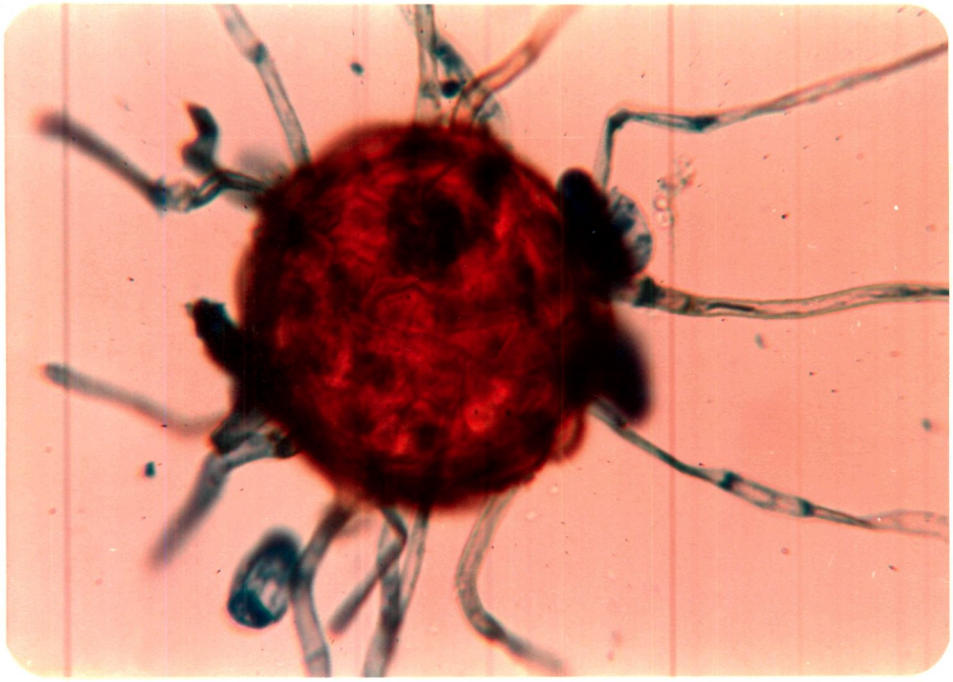


Fig-11

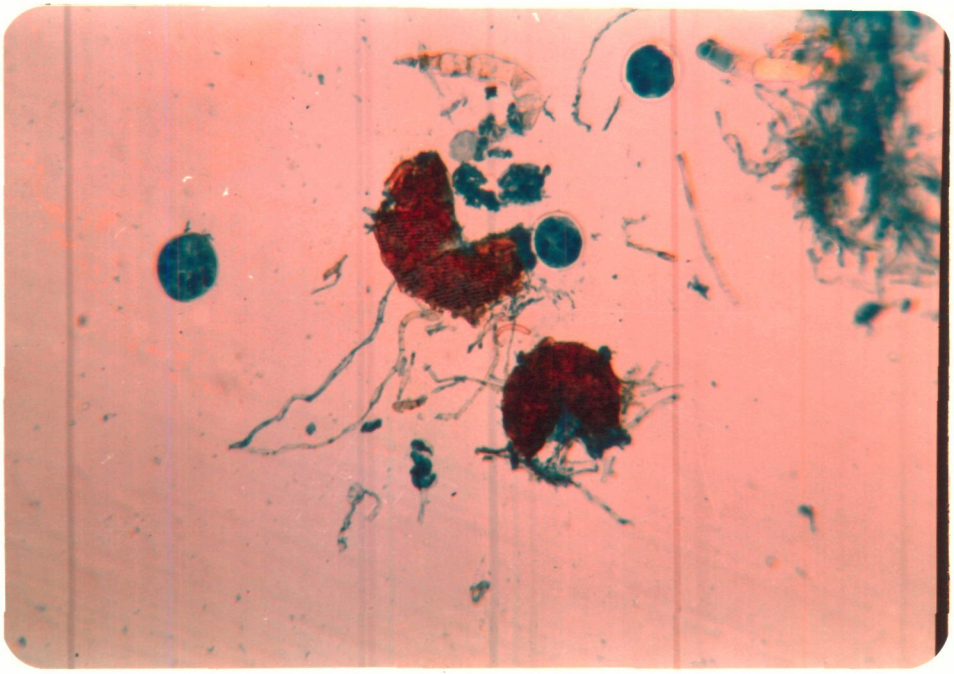
Fig. 12: Single unruptured perithecium.



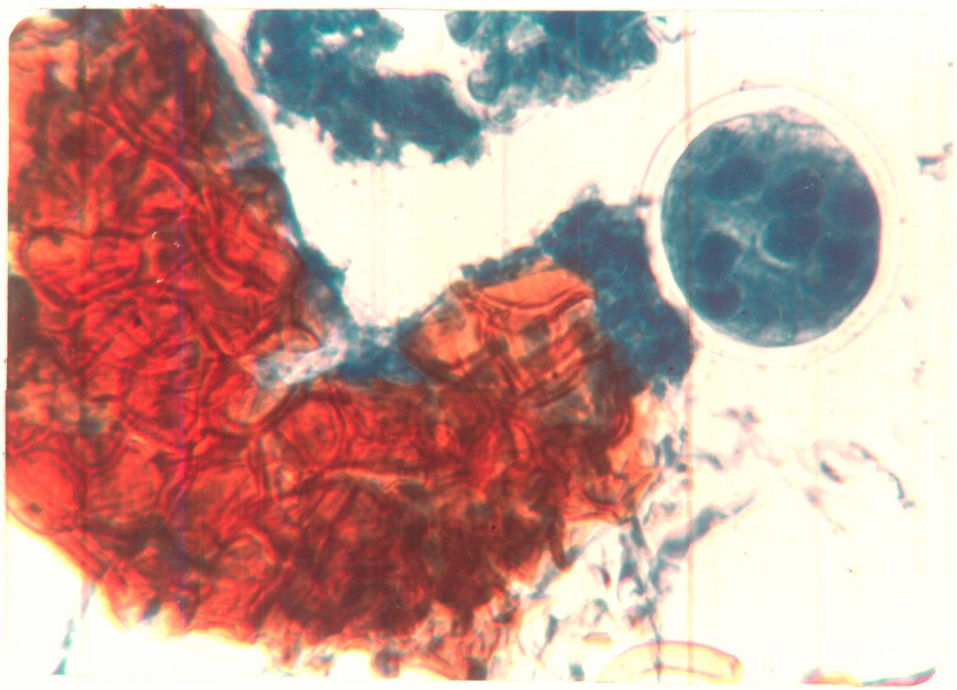
Fig·12

Fig. 13: (a) Ruptured perithecia of S. fuliginea with single ascus showing 7-8 ascospores.

(b) Close-up; showing ascus with 7 ascospores.



Fig·13(a)



Fig·13(b)

Fig. 14: (a) Leaves of Chrysanthemum carinatum infected with powdery mildew showing perithecia.

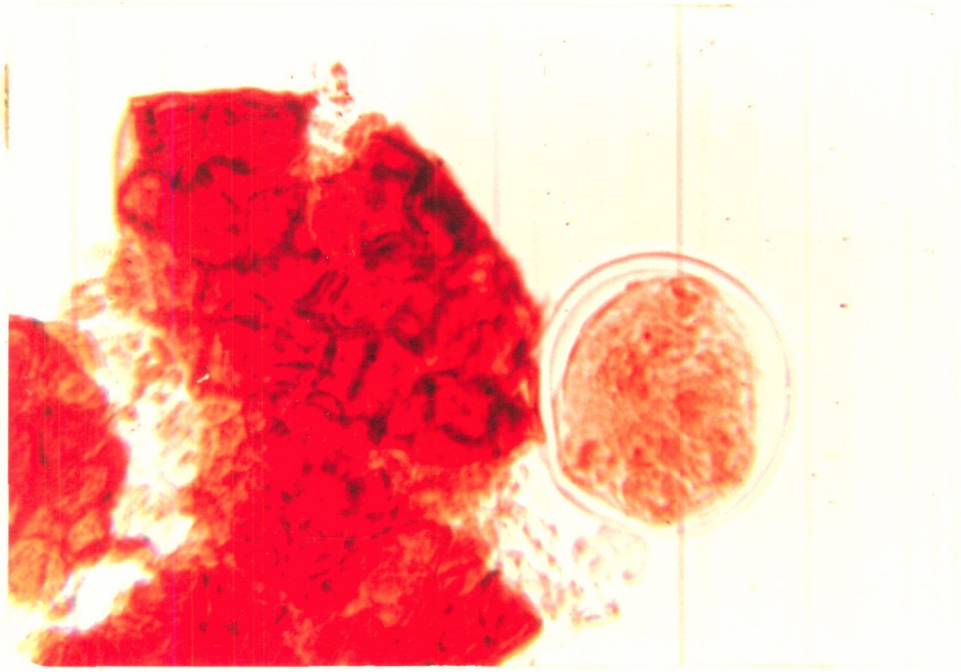
(b) Close-up of C. carinatum showing perithecia.

Fig·14 (a)

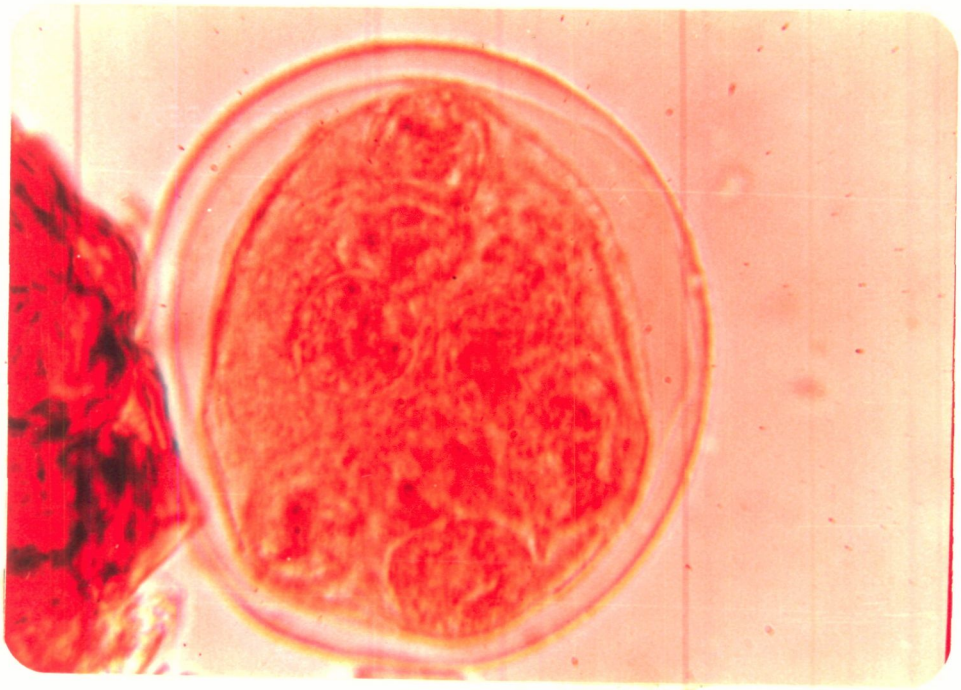
Fig·14 (b)

Fig. 15: (a) Ruptured perithecia of Sphaerotheca fuliginea from C. carinatum with single ascus.

(b) Close-up; showing ascus with 7 ascospores.



Fig·15(a)



Fig·15(b)

The size of perithecia of H. annuus and C. carinatum ranged from 101.5-112.0 (97.25) um diameter and 91.0-108.4 (99.27) x 91.0 - 105.0 (96.78) um in length and width respectively, while that of ascus ranged from 63.0-70.0 (66.50) x 61.0-68.0 (65.00) um and 63.0-98.0 (84.02) x 49.7-94.5 (77.88) um and the measurement of ascospores ranging from 13.3-14.0 (13.29) and 17.5-18.0 (17.50) um respectively (Table - 4). Thus, on the basis of these studies, it can be concluded that the perithecia on these hosts were of S. fuliginea and not of E. cichoracearum.

4.3. HOST RANGE: Out of twenty seven cultivated, ten wild and twenty three non-composites tested against Ec_1 (C. moschata), Ec_2 (Cineraria sp.), Ec_3 (D. variabilis), Ec_4 (V. cinerea) and Ec_5 (Z. elegans) isolates of E. cichoracearum collected from Aligarh and its adjoining areas and maintained in glasshouse for further studies.

It is clear from the Tables - 5-7 that the Cineraria sp., D. variabilis and Z. elegans were susceptible to the Ec_3 isolate in glasshouse as well as in field, whereas, L. sativa was susceptible to this isolate only in glasshouse. The Ec_5 isolate produced symptom on Cineraria sp., D. variabilis and H. annuus in addition to its respective host under both the condition. While Ec_1 and Ec_2 infect only their respective hosts in glasshouse and field conditions. Ec_4 was unable to produce powdery mildew disease even on its respective host. All the isolates of E. cichoracearum from

TABLE - 4:- Measurements of perithecia of powdery mildew of *Helianthus annuus* and *Chrysanthemum carinatum*.

Characters studied	Range with mean in um
Perithecia	
H. annuus	
Diameter	101.5-112.0(97.25)
C. carinatum	
Length x width	091.0-108.4(99.27) x 91.0-105.0(96.78)
Asci	
H. annuus	
Length x width	063.0-070.0(66.50) x 61.0-068.0(65.00)
C. carinatum	
Length x width	063.0-098.0(84.02) x 49.7-094.5(77.88)
Ascospores	
H. annuus	
Diameter	013.3-014.0(13.29)
C. carinatum	
Diameter	017.5-018.0(17.50)

Figures in ( ) indicate mean measurement.

TABLE - 5:- Reaction of twenty seven cultivated composites against E. cichoracearum when inoculated plants are grown in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Acroclinium sp.	R	R	R	R	R	R	R	R	R	R
Ageratum sp.	R	R	R	R	R	R	R	R	R	R
Arctotis sp.	R	R	R	R	R	R	R	R	R	R
Aster sp.	R	R	R	R	R	R	R	R	R	R
Bellis perennis	R	R	R	R	R	R	R	R	R	R
Brachycome iberidifolia	R	R	R	R	R	R	R	R	R	R
Cacalia coccinia	R	R	R	R	R	R	R	R	R	R
Calendula officinalis	R	R	R	R	R	R	R	R	R	R
Carthamus tinctorius	R	R	R	R	R	R	R	R	R	R
Centaurea cyanus	R	R	R	R	R	R	R	R	R	R
Centaurea moschata	S	S	R	R	R	R	R	R	R	R
Chrysanthemum carinatum	R	R	R	R	R	R	R	R	R	R
Cineraria sp.	R	R	S	S	S	S	R	R	S	S
Coreopsis sp.	R	R	R	R	R	R	R	R	R	R
Cosmos sulphonus	R	R	R	R	R	R	R	R	R	R
Dahlia variabilis	R	R	R	R	S	S	R	R	S	S
Dimorphotheca sinuata	R	R	R	R	R	R	R	R	R	R
Gaillardia sp.	R	R	R	R	R	R	R	R	R	R
Gamolepis tagetes	R	R	R	R	R	R	R	R	R	R
Gazania splendens	R	R	R	R	R	R	R	R	R	R
Helianthus annuus	R	R	R	R	R	R	R	R	S	S
Helichrysum bracteatum	R	R	R	R	R	R	R	R	R	R
Lactuca sativa	R	R	R	R	S	R	R	R	R	R
Tagetes erecta	R	R	R	R	R	R	R	R	R	R
Tithonia sp.	R	R	R	R	R	R	R	R	R	R
Venidium sp.	R	R	R	R	R	R	R	R	R	R
Zinnia elegans	R	R	R	R	S	S	R	R	S	S

Ec_1 = isolate from Centaurea moschata; Ec_2 = isolate from Cineraria sp.; *R = resistant;
Ec_3 = isolate from Dahlia variabilis; Ec_4 = isolate from Vernonia cinerea; *S = susceptible.
Ec_5 = isolate from Zinnia elegans; GH = glass house; F = field;

TABLE - 6:- Reaction of ten wild composites against *E. cichoracearum* when inoculated plants are grown in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Ageratum sp.	R	R	R	R	R	R	R	R	R	R
Cirsium arvens	R	R	R	R	R	R	R	R	R	R
Conyza japonica	R	R	R	R	R	R	R	R	R	R
Eclipta alba	R	R	R	R	R	R	R	R	R	R
Launaea procumbens	R	R	R	R	R	R	R	R	R	R
Pluchea sp.	R	R	R	R	R	R	R	R	R	R
Sonchus oleraceous	R	R	R	R	R	R	R	R	R	R
Tridax procumbens	R	R	R	R	R	R	R	R	R	R
Vernonia cinerea	R	R	R	R	R	R	R	R	R	R
Xanthium strumarium	R	R	R	R	R	R	R	R	R	R

Ec_1 = isolate from *Centaurea moschata*; Ec_2 = isolate from *Cineraria* sp.; *R = resistant.
Ec_3 = isolate from *Dahlia variabilis*; Ec_4 = isolate from *Vernonia cinerea*;
Ec_5 = isolate from *Zinnia elegans*; GH = glass house; F = field;

TABLE - 7:- Reaction of twenty three non-composites against *E. cichoracearum* when inoculated plants are grown in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Abelmoschus esculentus	R	R	R	R	R	R	R	R	R	R
Benincasa hispida	R	R	R	R	R	R	R	R	R	R
Cassia occidentalis	R	R	R	R	R	R	R	R	R	R
Chenopodium ambrosoides	R	R	R	R	R	R	R	R	R	R
Chenopodium album	R	R	R	R	R	R	R	R	R	R
Citrullus vulgaris	R	R	R	R	R	R	R	R	R	R
Cucurbita maxima	R	R	R	R	R	R	R	R	R	R
Cucurbita moschata	R	R	R	R	R	R	R	R	R	R
Cucumis melo	R	R	R	R	R	R	R	R	R	R
Cucumis sativus	R	R	R	R	R	R	R	R	R	R
Coccinia cordifolia	R	R	R	R	R	R	R	R	R	R
Gomphrena globosa	R	R	R	R	R	R	R	R	R	R
Lagenaria leucantha	R	R	R	R	R	R	R	R	R	R
Lathyrus odoratus	R	R	R	R	R	R	R	R	R	R
Lycopersicum esculentum	R	R	R	R	R	R	R	R	R	R
Momordica charantia	R	R	R	R	R	R	R	R	R	R
Nicotiana tabacum	R	R	R	R	R	R	R	R	R	R
Solanum melongena	R	R	R	R	R	R	R	R	R	R
Solanum nigrum	R	R	R	R	R	R	R	R	R	R
Solanum tuberosum	R	R	R	R	R	R	R	R	R	R
Salvia sp.	R	R	R	R	R	R	R	R	R	R
Trichosanthes anguina	R	R	R	R	R	R	R	R	R	R
Viola tricolor	R	R	R	R	R	R	R	R	R	R

Ec_1 = isolate from *Centaurea moschata*; Ec_2 = isolate from *Cineraria*; *R = resistant.
Ec_3 = isolate from *Dahlia variabilis*; Ec_4 = isolate from *Vernonia cinerea*;
Ec_5 = isolate from *Zinnia elegans*; GH = glass house; F = field.

above cited hosts failed to infect any of the tested wild and non-composites.

The isolates of S. fuliginea, designated as Sf_1, Sf_2, Sf_3, Sf_4, Sf_5, Sf_6 and Sf_7 from Acroclinium sp., C. tinctorius, C. carinatum, C. sulphonus, H. annuus, D. sinuata and X. strumarium respectively responded positively only on their respective hosts both in glass house and field conditions, except the Sf_7 isolate which also produced symptoms on cultivated C. coccinia in both the conditions (Tables - 8-10) Fig. 16.

B. perennis, B. iberidifolia and G. tagetes were identified as the hosts of Oidium spp. and were designed as O_1, O_2 and O_3 isolates respectively. They failed to infect the cultivated, and wild composites and non-composites except their respective hosts (Tables - 11-13).

The isolates of E. cichoracearum from non-composites viz. Ec_6 (C. cordifolia) and Ec_7 (B. hispida) were able to produce symptoms only on their respective hosts and failed to infect other tested plants including composites (Tables - 14-16).

4.4. VARIETAL SCREENING: Single variety of Cineraria sp. viz. large single superb mixed was highly susceptible, susceptible and resistant respectively against Ec_2, Ec_3 and Ec_5 isolates in glass house and field conditions (Table - 19).

Table - 20 (Fig.18) indicates that out of six varieties of D. variabilis viz. cactus mixed was resistant to Ec_3 and Ec_5

TABLE - 8:- Reaction of twenty seven cultivated composites against *S. fuliginea* when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES													
	Sf_1		Sf_2		Sf_3		Sf_4		Sf_5		Sf_6		Sf_7	
	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F
Acroclinium sp.	S	S	R	R	R	R	R	R	R	R	R	R	R	R
Ageratum sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Arctotis sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Aster sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Bellis perennis	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Brachycome iberidifolia	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cacalia coccinia	R	R	R	R	R	R	R	R	R	R	R	R	S	S
Calendula officinalis	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Carthamus tinctorius	R	R	S	S	R	R	R	R	R	R	R	R	R	R
Centaurea cyanus	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Centaurea moschata	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Chrysanthemum carinatum	R	R	R	R	S	S	R	R	R	R	R	R	R	R
Cineraria sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Coreopsis sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cosmos sulphonus	R	R	R	R	R	R	S	S	R	R	R	R	R	R
Dahlia variabilis	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Dimorphotheca sinuata	R	R	R	R	R	R	R	R	S	S	R	R	R	R
Gaillardia sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gamolepis tagetes	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gazania splendens	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Helianthus annuus	R	R	R	R	R	R	R	R	R	R	S	S	R	R
Helichrysum bracteatum	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Lactuca sativa	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tagetes erecta	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tithonia sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Venidium sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Zinnia elegans	R	R	R	R	R	R	R	R	R	R	R	R	R	R

*Sf_1 = *Acroclinium* sp.; Sf_2 = *Carthamus tinctorius*; Sf_3 = *Chrysanthemum carinatum*; GH = Glass house;
Sf_4 = *Cosmos sulphonus*; Sf_5 = *Dimorphotheca sinuata*; Sf_6 = *Helianthus annuus*; F = Field.
Sf_7 = *Xanthium strumarium*; S = Susceptible; R = Resistant;

TABLE - 9:- Reaction of ten wild composites against *S. fuliginea* when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES													
	Sf_1		Sf_2		Sf_3		Sf_4		Sf_5		Sf_6		Sf_7	
	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F
Ageratum sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cirsium arvens	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Conyza japonica	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Eclipta alba	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Launaea procumbens	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Pluchea sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Sonchus oleraceous	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Tridax procumbens	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Vernonia cinerea	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Xanthium strumarium	R	R	R	R	R	R	R	R	R	R	R	R	S	S

*Sf_1 = *Acroclinium* sp.; Sf_2 = *Carthamus tinctorius*; Sf_3 = *Chrysanthemum carinatum*; GH = Glass house;
Sf_4 = *Cosmos sulphonus*; Sf_5 = *Dimorphotheca sinuata*; Sf_6 = *Helianthus annuus*; F = Field.
Sf_7 = *Xanthium strumarium*; R = Resistant; S = Susceptible;

TABLE - 10:- Reaction of twenty three non-composites against *S. fuliginea* when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES													
	Sf_1		Sf_2		Sf_3		Sf_4		Sf_5		Sf_6		Sf_7	
	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F	GH	F
Abelmoschus esculentus	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Benincasa hispida	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cassia occidentalis	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Chenopodium ambrosoides	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Chenopodium album	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Citrullus vulgaris	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Coccinia cordifolia	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cucurbita maxima	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cucurbita moschata	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cucumis melo	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Cucumis sativus	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gomphrena globosa	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Lagenaria leucantha	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Lathyrus odoratus	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Lycopersicum esculentum	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Momordica charantia	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Nicotiana tabacum	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Solanum melongena	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Solanum nigrum	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Solanum tuberosum	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Salvia sp.	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Trichosanthes anguina	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Viola tricolor	R	R	R	R	R	R	R	R	R	R	R	R	R	R

*Sf_1 = *Acroclinium* sp.; Sf_2 = *Carthamus tinctorius*; Sf_3 = *Chrysanthemum carinatum*; GH = Glass house;
Sf_4 = *Cosmos sulphonus*; Sf_5 = *Dimorphotheca sinuata*; SF_6 = *Helianthus annuus*; F = Field.
Sf_7 = *Xanthium strumarium*; R = Resistant;

Fig. 16: Cacalia coccinia infected with S. fuliginea isolate from Xanthium strumarium.

Fig·16

TABLE - 11:- Reaction of twenty seven cultivated composites against *Oidium* spp. when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES					
	O_1		O_2		O_3	
	GH	F	GH	F	GH	F
Acroclinium sp.	R	R	R	R	R	R
Ageratum sp.	R	R	R	R	R	R
Arctotis sp	R	R	R	R	R	R
Bellis perennis	S	S	R	R	R	R
Brachycome iberidifolia	R	R	S	S	R	R
Cacalia coccinia	R	R	R	R	R	R
Calendula officinalis	R	R	R	R	R	R
Carthamus tinctorius	R	R	R	R	R	R
Centaurea cyanus	R	R	R	R	R	R
Centaurea moschata	R	R	R	R	R	R
Chrysanthemum carinatum	R	R	R	R	R	R
Cineraria sp.	R	R	R	R	R	R
Coreopsis sp.	R	R	R	R	R	R
Cosmos sulphonus	R	R	R	R	R	R
Dahlia variabilis	R	R	R	R	R	R
Dimorphotheca sinuata	R	R	R	R	R	R
Gaillardia sp.	R	R	R	R	R	R
Gamolepis tagetes	R	R	R	R	S	S
Gazania splendens	R	R	R	R	R	R
Helianthus annuus	R	R	R	R	R	R
Helichrysum bracteatum	R	R	R	R	R	R
Lactuca sativa	R	R	R	R	R	R
Tagetes erecta	R	R	R	R	R	R
Tithonia sp.	R	R	R	R	R	R
Venidium sp.	R	R	R	R	R	R
Zinnia elegans	R	R	R	R	R	R

*O_1 = *Bellis perennis*; O_2 = *Brachycome iberidifolia*; GH = Glass house;
O_3 = *Gamolepis tagetes*; R = Resistant; S = Susceptible; F = Field.

TABLE - 12:- Reaction of ten wild composites against Oidium spp. when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES					
	O_1		O_2		O_3	
	GH	F	GH	F	GH	F
Ageratum sp.	R	R	R	R	R	R
Cirsium arvens	R	R	R	R	R	R
Conyza japonica	R	R	R	R	R	R
Eclipta alba	R	R	R	R	R	R
Launaea procumbens	R	R	R	R	R	R
Pluchea sp.	R	R	R	R	R	R
Sonchus oleraceous	R	R	R	R	R	R
Tridax procumbens	R	R	R	R	R	R
Vernonia cinerea	R	R	R	R	R	R
Xanthium strumarium	R	R	R	R	R	R

*O_1 = Bellis perennis; O_2 = Brachycome iberidifolia; GH = Glass house;
O_3 = Gamolepis tagetes; R = Resistant; F = Field.

TABLE - 13:- Reaction of twenty three non-composites against Oidium spp. when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES					
	O_1		O_2		O_3	
	GH	F	GH	F	GH	F
Abelmoschus esculentus	R	R	R	R	R	R
Benincasa hispida	R	R	R	R	R	R
Cassia occidentalis	R	R	R	R	R	R
Chenopodium ambrosoides	R	R	R	R	R	R
Chenopodium album	R	R	R	R	R	R
Citrullus vulgaris	R	R	R	R	R	R
Coccinia cordifolia	R	R	R	R	R	R
Cucurbita maxima	R	R	R	R	R	R
Cucurbita moschata	R	R	R	R	R	R
Cucumis melo	R	R	R	R	R	R
Cucumis sativus	R	R	R	R	R	R
Gomphrena globosa	R	R	R	R	R	R
Lagenaria leucantha	R	R	R	R	R	R
Lathyrus odoratus	R	R	R	R	R	R
Lycopersicum esculentum	R	R	R	R	R	R
Momordica charantia	R	R	R	R	R	R
Nicotiana tabacum	R	R	R	R	R	R
Solanum melongena	R	R	R	R	R	R
Solanum nigrum	R	R	R	R	R	R
Solanum tuberosum	R	R	R	R	R	R
Salvia sp.	R	R	R	R	R	R
Trichosanthes anguina	R	R	R	R	R	R
Viola tricolor	R	R	R	R	R	R

*O_1 = Bellis perennis; O_2 = Brachycome iberidifolia; GH = Glass house;
O_3 = Gamolepis tagetes; R = Resistant; F = Field.

TABLE - 14:- Reaction of twenty seven cultivated composites against Erysiphe cichoracearum obtained from non-composites when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES			
	Coccinia cordifolia		Benincasa hispida	
	Glass house	Field	Glass house	Field
Acroclinium sp.	R	R	R	R
Ageratum sp.	R	R	R	R
Arctotis sp.	R	R	R	R
Aster sp.	R	R	R	R
Bellis perennis	R	R	R	R
Brachycome iberidifolia	R	R	R	R
Cacalia coccinia	R	R	R	R
Calendula officinalis	R	R	R	R
Carthamus tinctorius	R	R	R	R
Centaurea cyanus	R	R	R	R
Centaurea moschata	R	R	R	R
Chrysanthemum carinatum	R	R	R	R
Cineraria sp.	R	R	R	R
Coreopsis sp.	R	R	R	R
Cosmos sulphonus	R	R	R	R
Dahlia variabilis	R	R	R	R
Dimorphotheca sinuata	R	R	R	R
Gaillardia sp.	R	R	R	R
Gamolepis tagetes	R	R	R	R
Gazania splendens	R	R	R	R
Helianthus annuus	R	R	R	R
Helichrysum bracteatum	R	R	R	R
Lactuca sativa	R	R	R	R
Tagetes erecta	R	R	R	R
Tithonia sp.	R	R	R	R
Venidium sp.	R	R	R	R
Zinnia elegans	R	R	R	R

*R = Resistant.

TABLE - 15:- Reaction of ten wild composites against Erysiphe cichoracearum obtained from non-composites when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES			
	Coccinia cordifolia		Benincasa hispida	
	Glass house	Field	Glass house	Field
Ageratum sp.	R	R	R	R
Cirsium arvens	R	R	R	R
Conyza japonica	R	R	R	R
Eclipta alba	R	R	R	R
Launaea procumbens	R	R	R	R
Pluchea sp.	R	R	R	R
Sonchus oleraceous	R	R	R	R
Tridax procumbens	R	R	R	R
Vernonia cinerea	R	R	R	R
Xanthium strumarium	R	R	R	R

*R = Resistant.

TABLE - 16:- Reaction of twenty three non-composites against *E. cichoracearum* obtained from non-composites when inoculated plants are grown either in glass house or in the field.

PLANTS INOCULATED	*REACTION AGAINST ISOLATES			
	Coccinia cordifolia		*Benincasa hispida*	
	Glass house	Field	Glass house	Field
Abelmoschus esculentus	R	R	R	R
Benincasa hispida	R	R	S	S
Cassia occidentalis	R	R	R	R
Chenopodium ambrosoides	R	R	R	R
Chenopodium album	R	R	R	R
Citrullus vulgaris	R	R	R	R
Coccinia cordifolia	S	S	R	R
Cucurbita maxima	R	R	R	R
Cucurbita moschata	R	R	R	R
Cucumis melo	R	R	R	R
Cucumis sativus	R	R	R	R
Gomphrena globosa	R	R	R	R
Lagenaria leucantha	R	R	R	R
Lathyrus odoratus	R	R	R	R
Lycopersicum esculentum	R	R	R	R
Momordica charantia	R	R	R	R
Nicotiana tabacum	R	R	R	R
Solanum melongena	R	R	R	R
Solanum nigrum	R	R	R	R
Solanum tuberosum	R	R	R	R
Salvia sp.	R	R	R	R
Trichosanthes anguina	R	R	R	R
Viola tricolor	R	R	R	R

*R = Resistant; S = Susceptible.

Fig. 17: Leaves of D. variabilis showing disease rating; Highly resistant = 0; Resistant = 1; Susceptible = 2 and Highly susceptible = 3.

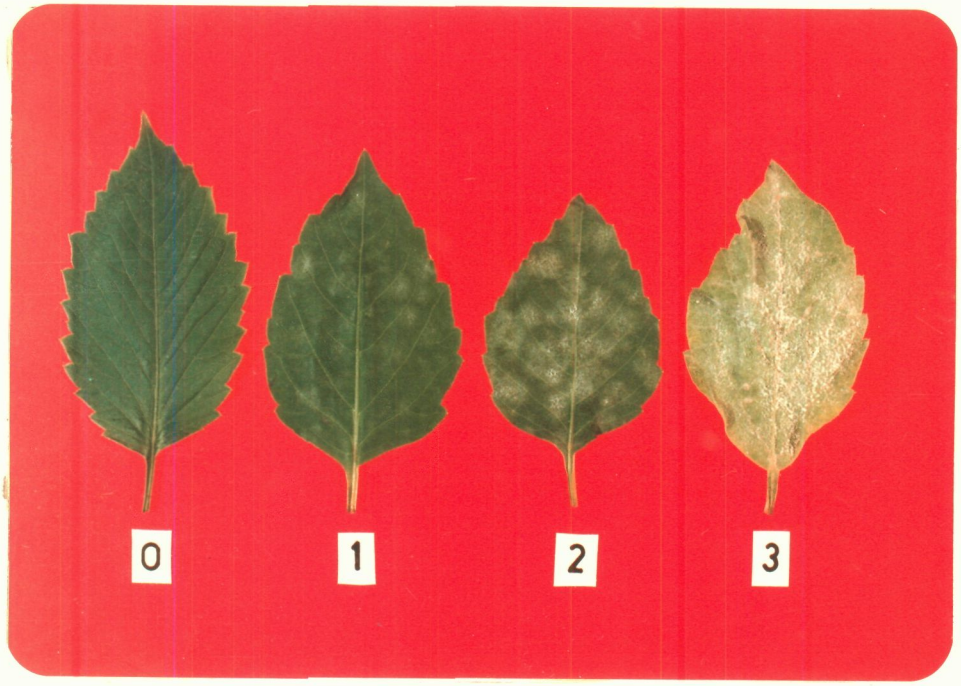


Fig-17

TABLE - 19:- Reaction of four different varieties of *Coreopsis* sp., ten of *Cosmos sulphonus* and one of *Cineraria* sp. against *E. cichoracearum* when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Coreopsis sp.										
Dwarf mixed	0	0	0	0	0	0	0	0	0	0
Tall mixed	0	0	0	0	0	0	0	0	0	0
Picta	0	0	0	0	0	0	0	0	0	0
Grandiflora double	0	0	0	0	0	0	0	0	0	0
Cosmos sulphonus										
Alipore beauty	0	0	0	0	0	0	0	0	0	0
Klondyke mixed	0	0	0	0	0	0	0	0	0	0
Single mixed	0	0	0	0	0	0	0	0	0	0
Double mixed	0	0	0	0	0	0	0	0	0	0
Tall orange	0	0	0	0	0	0	0	0	0	0
Purity	0	0	0	0	0	0	0	0	0	0
Cosmos mixed	0	0	0	0	0	0	0	0	0	0
Pinkie	0	0	0	0	0	0	0	0	0	0
Double crosted mixed	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0
Cineraria sp.										
Large single superb mixed	0	0	3	3	2	2	0	0	1	1

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; Ec_3 = *Dahlia variabilis*; GH = Glass house;
Ec_4 = *Vernonia cinerea*; Ec_5 = *Zinnia elegans*; 3 = Highly susceptible; F = Field.
2 = Susceptible; 1 = Resistant; 0 = Highly resistant;

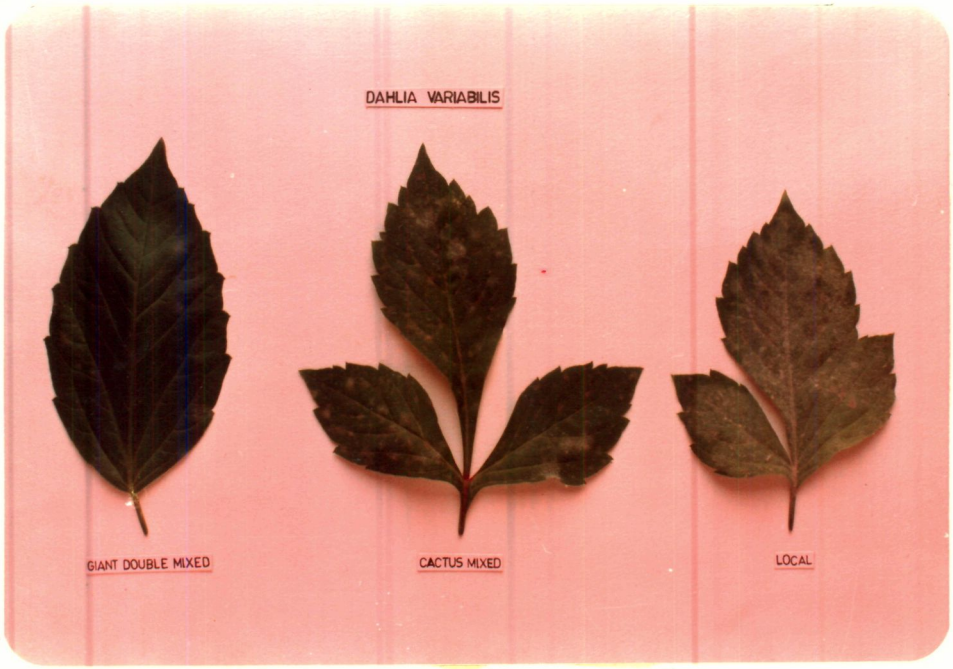
TABLE - 20:- Reaction of six different varieties of *Dahlia variabilis* and four of *Dimorphotheca sinuata* against *E. cichoracearum* when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Dahlia variabilis										
Double mixed	0	0	0	0	0	0	0	0	0	0
Unwins dwarf mixed	0	0	0	0	0	0	0	0	0	0
Large fld. mixed	0	0	0	0	0	0	0	0	0	0
Giant double mixed	0	0	0	0	0	0	0	0	0	0
Cactus mixed	0	0	0	0	1	0	0	0	1	0
Local	0	0	2	1	3	3	0	0	1	1
Dimorphotheca sinuata										
Glistening white	0	0	0	0	0	0	0	0	0	0
Special mixture	0	0	0	0	0	0	0	0	0	0
Giant orange	0	0	0	0	0	0	0	0	0	0
Mixed	0	0	0	0	0	0	0	0	0	0

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; Ec_3 = *Dahlia variabilis*; Ec_4 = *Vernonia cinerea*; Ec_5 = *Zinnia elegans*; 3 = Highly susceptible; 2 = Susceptible; 1 = Resistant; 0 = Highly resistant;

GH = Glass house; F = Field.

Fig. 18: Varieties of D. variabilis showing resistant, susceptible and highly susceptible.



Fig·18

isolates in glass house but highly resistant in the field; local was susceptible in glass house and resistant in the field against Ec_2 isolate, on the other hand it was highly susceptible and resistant against Ec_3 and Ec_5 isolates respectively in glass house as well as in the field.

Table - 23 clearly indicates that out of three varieties of L. sativa, only local was found to be resistant against Ec_3 in glass house but highly resistant in field conditions. The remaining varieties were highly resistant to the remaining four isolates in glass house as well as in the field.

Amongst thirty varieties of Z. elegans tested, only haageana hybrid was resistant to Ec_3 isolate in glass house but highly resistant under field conditions. Haageana hybrid and golden yellow were susceptible while scarlet red was highly susceptible and lilliput was resistant Ec_5 isolate in glass house as well as in the field. The remaining varieties were highly resistant to all five isolates (Table - 25).

All the varieties of Acroclinium sp., Arctotis sp., Aster sp. C. officinalis, C. tinctorius, C. carinatum, Coreopsis sp., C. sulphonus, D. sinuata, Gaillardia sp., G. splendens, H. annuus, H. bracteatum and T. erecta were highly resistant to Ec_1, Ec_2, Ec_3, Ec_4 and Ec_5 isolates in glass house as well as in the field (Tables - 17-22 & 24).

4.5. COMMON HOST TEST: Since H. annuus has been reported a common host of both E. cichoracearum and S. fuliginea. It was considered desirable to study the development of two pathogens on

TABLE - 17:- Reaction of two different varieties of Acroclinium sp., two of Arctotis sp. and four of Aster sp. against E. cichoracearum when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Acroclinium sp.										
Special mixture	0	0	0	0	0	0	0	0	0	0
Spendens mixed	0	0	0	0	0	0	0	0	0	0
Artotis sp.										
Grandis hybrid	0	0	0	0	0	0	0	0	0	0
Special hybrid	0	0	0	0	0	0	0	0	0	0
Aster sp.										
California giants mixed	0	0	0	0	0	0	0	0	0	0
Powder puff mixed	0	0	0	0	0	0	0	0	0	0
Giant mixed	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; GH = Glass house;
Ec_2 = *Dahlia variabilis*; Ec_4 = *Vernonia cinerea*; F = Field.
Ec_5 = *Zinnia elegans*; O = Highly resistant;

TABLE - 18:- Reaction of eight different varieties of *Calendula officinalis*, one of *Carthamus tinctorius* and three of *Chrysanthemum carinatum* against *E. cichoracearum* when inoculated plants are grown either in glass house or in the field.

VARIEITES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Calendula officinalis										
Orange king	0	0	0	0	0	0	0	0	0	0
Lemon queen	0	0	0	0	0	0	0	0	0	0
Orange coronet	0	0	0	0	0	0	0	0	0	0
Art shades	0	0	0	0	0	0	0	0	0	0
Double mixed$_1$	0	0	0	0	0	0	0	0	0	0
Fiesta gitana	0	0	0	0	0	0	0	0	0	0
Double mixed$_2$	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	
Carthamus tinctorius										
Kinko	0	0	0	0	0	0	0	0	0	0
Chrysanthemum carinatum										
Coronarium mixed	0	0	0	0	0	0	0	0	0	0
Fine mixed	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; GH = Glass house;
Ec_3 = *Dahlia variabilis*; Ec_4 = *Vernonia cinerea*; F = Field.
Ec_5 = *Zinnia elegans*; 0 = Highly resistant;

TABLE - 21:- Reaction of three different varieties of *Gaillardia* sp. and two of *Gazania splendens* against *E. cichoracearum* when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Gaillardia sp.										
Double mixed	0	0	0	0	0	0	0	0	0	0
Lorenziana single mixed	0	0	0	0	0	0	0	0	0	0
Lollypop yellow	0	0	0	0	0	0	0	0	0	0
Gazania splendens										
Sunshine hybrid mixed	0	0	0	0	0	0	0	0	0	0
Hybrid mixed	0	0	0	0	0	0	0	0	0	0

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; Ec_3 = *Dahlia variabilis*; GH = Glass house;
Ec_4 = *Vernonia cinerea*; Ec_5 = *Zinnia elegans*; 0 = Highly resistant; F = Field.

TABLE - 22:- Reaction of eleven different varieties of Helianthus annuus and three of Helichrysum bracteatum against E. cichoracearum when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Helianthus annuus										
Double chrysanthemum fld.	0	0	0	0	0	0	0	0	0	0
Sungold dwarf	0	0	0	0	0	0	0	0	0	0
Chrysanthemum fld. mixed	0	0	0	0	0	0	0	0	0	0
Sunburst	0	0	0	0	0	0	0	0	0	0
Double orange	0	0	0	0	0	0	0	0	0	0
Dwarf sungold	0	0	0	0	0	0	0	0	0	0
Bronze hybrid	0	0	0	0	0	0	0	0	0	0
Double sungold	0	0	0	0	0	0	0	0	0	0
Japanees single maniature	0	0	0	0	0	0	0	0	0	0
$Local_1$	0	0	0	0	0	0	0	0	0	0
$Local_2$	0	0	0	0	0	0	0	0	0	0
Helichrysum bracteatum										
Large fld. mixed	0	0	0	0	0	0	0	0	0	0
Double mixed	0	0	0	0	0	0	0	0	0	0
Choice mixed	0	0	0	0	0	0	0	0	0	0

*Ec_1 = Centaurea moschata; Ec_2 = Cineraria sp.; GH = Glass house;
Ec_3 = Dahlia variabilis; Ec_4 = Vernonia cinerea; F = Field.
Ec_5 = Zinnia elegans; 0 = Highly resistant;

TABLE - 23:- Reaction of three different varieties of Lactuca sativa against E. cichoracearum when inoculated plants are grown either in glass house or in the field.

VARIETIES	*RECTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Paris whitecos	0	0	0	0	0	0	0	0	0	0
Ice berg	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	1	0	0	0	0	0

*Ec_1 = Centaruea moschata; Ec_2 = Cineraria sp.; Ec_3 = Dahlia variabilis; GH = Glass house;
Ec_4 = Vernonia cinerea; Ec_5 = Zinnia elegans; F = Field.
1 = Resistant; 0 = Highly resistant;

TABLE - 24:- Reaction of fifteen different varieties of *Tagetes erecta* against *E. cichoracearum* when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Double mixed	0	0	0	0	0	0	0	0	0	0
French petite mixed	0	0	0	0	0	0	0	0	0	0
Giant double African mixed	0	0	0	0	0	0	0	0	0	0
Giant double lemon	0	0	0	0	0	0	0	0	0	0
Giant double orange	0	0	0	0	0	0	0	0	0	0
French red brocade	0	0	0	0	0	0	0	0	0	0
Sunset giants mixed	0	0	0	0	0	0	0	0	0	0
Cupid yellow	0	0	0	0	0	0	0	0	0	0
Dwarf harmony	0	0	0	0	0	0	0	0	0	0
Hybrid gee whiz lemon	0	0	0	0	0	0	0	0	0	0
Tall African mixed	0	0	0	0	0	0	0	0	0	0
French dwarf mixed	0	0	0	0	0	0	0	0	0	0
Crackerjack	0	0	0	0	0	0	0	0	0	0
Chrysanthemum fld. mixed	0	0	0	0	0	0	0	0	0	0
Local	0	0	0	0	0	0	0	0	0	0

*Ec_1 = *Centaurea moschata*; Ec_2 = *Cineraria* sp.; GH = Glass house;
Ec_3 = *Dahlia variabilis*; Ec_4 = *Vernonia cinerea*; F = Field.
Ec_5 = *Zinnia elegans*; 0 = Highly resistant;

TABLE - 25:- Reaction of thirty different varieties of Zinnia elegans against E. cichoracearum when inoculated plants are grown either in glass house or in the field.

VARIETIES	*REACTION AGAINST ISOLATES									
	Ec_1		Ec_2		Ec_3		Ec_4		Ec_5	
	GH	F	GH	F	GH	F	GH	F	GH	F
Giant hybrid mixed	0	0	0	0	0	0	0	0	0	0
Dahlia fld. polar bear	0	0	0	0	0	0	0	0	0	0
Dahlia fld. scarlet flame	0	0	0	0	0	0	0	0	0	0
Dahlia fld. purple prince	0	0	0	0	0	0	0	0	0	0
Elegans choice mixed	0	0	0	0	0	0	0	0	0	0
Dahlia fld. mixed envy green	0	0	0	0	0	0	0	0	0	0
Giant dahlia fld. mixed	0	0	0	0	0	0	0	0	0	0
Dahlia fld. royal purple	0	0	0	0	0	0	0	0	0	0
Dahlia fld. golden state	0	0	0	0	0	0	0	0	0	0
Giant dahlia illumination	0	0	0	0	0	0	0	0	0	0
Dahlia fld. golden dawn	0	0	0	0	0	0	0	0	0	0
Dahlia fld. crimson monarch	0	0	0	0	0	0	0	0	0	0
Dahlia fld. dream	0	0	0	0	0	0	0	0	0	0
Equisite	0	0	0	0	0	0	0	0	0	0
Dahlia fld. oriole	0	0	0	0	0	0	0	0	0	0
California giant mixed	0	0	0	0	0	0	0	0	0	0
Lilliput mixed	0	0	0	0	0	0	0	0	0	0
Rich salmon rose	0	0	0	0	0	0	0	0	0	0
Giant double yellow	0	0	0	0	0	0	0	0	0	0
Giant double orange	0	0	0	0	0	0	0	0	0	0
Persian carpet	0	0	0	0	0	0	0	0	0	0
Linearis orange	0	0	0	0	0	0	0	0	0	0
Haageana hybrid	0	0	0	0	1	0	0	0	2	2
Scarlet red	0	0	0	0	0	0	0	0	3	3
Lilliput	0	0	0	0	0	0	0	0	1	1
Golden yellow	0	0	0	0	0	0	0	0	2	2
Double yellow	0	0	0	0	0	0	0	0	0	0
White	0	0	0	0	0	0	0	0	0	0
Giant double white	0	0	0	0	0	0	0	0	0	0
Dahlia fld. mixed	0	0	0	0	0	0	0	0	0	0

*Ec_1 = Centaurea moschata; Ec_2 = Cineraria sp.; Ec_3 = Dahlia variabilis; GH = Glass house;
Ec_4 = Vernonia cinerea; Ec_5 = Zinnia elegans; 3 = Highly susceptible;
2 = Susceptible; 1 = Resistant; 0 = Highly resistant; F = Field.

this host, when inoculated simultaneously. Only a moderate infection was recorded with E. cichoracearum isolate from Z. elegans but severe with S. fuliginea isolate from H. annuus. Fifty percent of the same leaf, when concomitantly inoculated with E. cichoracearum and S. fuliginea, both pathogens competed very well on the same host and on the same leaf and both of them developed the symptoms (Table - 26).

However, after artificial inoculations perithecia of either E. cichoracearum and S. fuliginea had not been observed, therefore, only their mycelial and conidial characters were taken into consideration for detailed studies.

4.6. GERMINATION OF CONIDIA OF E. CICHORACEARUM:

(1) Effect of temperature on germination:- It is evident from the table - 27 that the conidia of E. cichoracearum obtained from D. variabilis and Z. elegans were failed to germinate at 5°C, whereas, the germination was initiated after 12 hours at 10, 15, 20, 25 and 30°C. At 10°C the percentage germination was very low after 72 hours. The highest germination was calculated after 72 hours at the temperature ranged from 15-20°C. The maximum percentage of germination of conidia from D. variabilis and Z. elegans was noted at 20°C as 64.3 and 67.2 at 100 percent relative humidity respectively. The germinated conidia deformed after 60 hours at 25°C, whereas, at 30°C the germination of conidia was in traces upto 24 hours. Later, they showed deformation after 36

TABLE - 26:- *Helianthus annuuss*, a common host for *Erysiphe cichoracearum* and *Sphaerotheca fuliginea*.

Treatments	Appearance of mildew	Production of perithecia
Leaves inoculated with *Erysiphe cichoracearum* only.	Moderate	--
Leaves inoculated with *Sphaerotheca fuliginea* only.	Severe	--
Erysiphe cichoracearum and *Sphaerotheca fuliginea* both inoculated on different leaves of the same plant.	Mildew appeared by the both pathogens	--
Half portion of leaf inoculated with *E. cichoracearum* and half with *S. fuliginea*.	Both pathogens produces symptoms on the same leaf.	--
Control	--	--

TABLE - 27:- Germination of conidia of Erysiphe cichoracearum from two composites at different temperatures and 100 percent relative humidity.

Temperatures in °C	PERCENTAGE GERMINATION OF CONIDIA AFTER													
	8 hrs.		12 hrs.		24 hrs.		36 hrs.		48 hrs.		60 hrs.		72 hrs.	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	T	-	07.3	T	11.6	06.2	15.0
15	-	-	22.8	24.8	23.2	24.9	30.2	38.9	48.5	51.3	48.6	52.0	48.6	58.0
20	-	-	24.3	25.6	44.5	52.3	47.3	53.4	49.0	56.1	53.2	57.0	64.3	67.2
25	-	-	30.2	36.0	52.7	54.2	52.8	56.0	53.0	56.4	54.2	Td	Td	Td
30	-	-	T	T	T	T	Td	Td	Td	Td	Td	Td	Td	Td

1 = Dahlia variabilis;
2 = Zinnia elegans;

- = No germination; T = Germination in trace;
Td = Germination in trace but conidia deformed.

hours of incubation.

(2) Effect of relative humidity on germination:- Table - 28 indicates that the isolated conidia of E. cichoracearum from D. variabilis and Z. elegans were failed to germinate at 66, 78 and 81 percent relative humidities, while they start germination at 90, 95 and 100 percent relative humidities after 12 hours of incubation. The highest germination was noted at 95-100 percent relative humidities after 72 hours. The maximum germination of conidia of E. cichoracearum was observed at 90, 95 and 100 percent relative humidities at 20°C after 72 hours, percentage germination was 64.0, 65.4 and 68.0 for D. variabilis and 60.0, 63.0 and 64.2 for Z. elegans isolates respectively. While, on the other hand conidia of E. cichoracearum from these plants were failed to germinate in free water.

4.7. EFFECT OF DIFFERENT TEMPERATURES AND RELATIVE HUMIDITY ON THE DEVELOPMENT OF POWDERY MILDEW ON DETACHED LEAVE OF ZINNIA ELEGANS INOCULATED WITH ERYSIPHE CICHORACEARUM: It is evident from the table - 29 that the varieties of Z. elegans viz. lilliput developed disease on eighth day, whereas, golden yellow and haageana hybrid produced symptoms on seventh day after inoculation at 15°C and 95 percent relative humidity respectively. Above said varieties gave positive response on fifth day after inoculation at 20 and 25°C respectively but the disease failed to appear at 5 and 10°C, the relative humidity being constant at 95 percent.

TABLE - 28:- Germination of conidia of Erysiphe cichoracearum from two composites at different rlative humidities and 20°C.

Relative humidity in percentage	PERCENTAGE GERMINATION OF CONIDIA AFTER													
	8 hrs.		12 hrs.		24 hrs.		36 hrs.		48 hrs.		60 hrs.		72 hrs.	
	1	2	1	2	1	2	1	2	1	2	1	2	1	2
66	-	-	-	-	-	-	-	-	-	-	-	-	-	-
78	-	-	-	-	-	-	-	-	-	-	-	-	-	-
81	-	-	-	-	-	-	-	-	-	-	-	-	-	-
90	-	-	48.3	56.4	60.8	58.2	63.0	59.5	63.6	59.5	62.0	60.0	64.0	60.0
95	-	-	54.0	58.2	59.3	61.4	65.2	62.0	65.3	62.0	65.3	63.0	65.4	63.0
100	-	-	55.0	60.0	64.3	60.7	66.0	62.0	66.5	62.3	67.8	63.0	68.0	64.2
Water	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1 = Dahlia variabilis;

2 = Zinnia elegans;

- = No germination.

TABLE - 29:- Effect of different temperatures at 95 percent relative humidity for appearance of powdery mildew on detached leaves of different varieties of *Zinnia elegans* inoculated with *Erysiphe cichoracearum*

VARIETIES	5°C	10°C	15°C	20°C	25°C
Lilliput	(-)	(-)	(8)	(5)	(5)
Golden yellow	(-)	(-)	(7)	(5)	(5)
Haageana hybrid	(-)	(-)	(7)	(5)	(5)

(-) = Powdery mildew not appeared.

Figure in ( ) indicate the time in days for the appearance of powdery mildew.

Table - 30 indicates that at 20°C and 81 percent relative humidity the disease appeared on sixth day on lilliput and golden yellow, whereas, the haageana hybrid developed symptoms on the fifth day respectively. On the other hand at 90 and 95 percent relative humidities all three varieties produced symptoms on the fifth day after inoculation keeping the temperature fixed at 20°C.

4.8. GERMINATION OF ASCOSPORES: It is clear from the table - 31 that the perithecia of S. fulginea from H. annuus and C. carinatum when exposed to soil environment later placed at a wide range of temperatures failed to discharge ascospores and no infection took place on test plants. Similarly, incubated on glass slides and placed in incubation chamber failed to germinate.

It is, therefore, concluded that even a prolonged expoure of perithecia (220 days) to soil environment does not help in the maturation of ascospores.

TABLE - 30:- Effect of different relative humidities at 20°C temperature for the appearance of powdery mildew on detached leaves of different varieties of Zinnia elegans inoculated with Erysiphe cichoracearum

VARIETIES	81%	90%	95%
Lilliput	(6)	(5)	(5)
Golden yellow	(6)	(5)	(5)
Haageana hybrid	(5)	(5)	(5)

Figure in ( ) indicate the time in days for the appearance of powdery mildew.

TABLE - 31:- Temperatures to which perithecia were exposed prior to transferring them either to humidity chamber or to the temperature cabinets.

NO. OF DAYS/HOSTS		TEMPERATURES IN °C						COMBINATIONS OF TEMPERATURES IN °C					
		-5	5	10	20	25	30	5&15	5&20	5&25	10&15	10&20	10&25
10	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
20	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
40	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
60	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
80	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
100	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
120	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
140	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
160	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
180	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
200	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-
220	C. carinatum	-	-	-	-	-	-	-	-	-	-	-	-
	H. annuus	-	-	-	-	-	-	-	-	-	-	-	-

C. carinatum = Chrysanthemum carintum; H. annuus = Helianthus annuus; - = No germination.

Chapter 5

Discussions & Conclusion

C H A P T E R - 5

DISCUSSIONS AND CONCLUSION

Powdery mildew have been known to take a heavy toll of various crops every year throughout the world. This is more true with India, where little work has been carried out on the biology of the pathogens responsible for this disease. Present investigation is an attempt to identify the pathogens causing powdery mildew and to assess the extent of damage caused by them on the members of the family Compositae. Although a considerable work has been carried out on various aspects of cucurbit powdery mildews both in India and elsewhere, but the work on the members of Compositae was so meager that its various aspects were in dilemma, that is why this work was undertaken.

During the survey, the powdery mildew of composites appears in two flushes, one from January to March and other from October to December (Tables - 1-2). It is understandable that during these periods both temperature and relative humidity are moderate and highly favourable for the development of the disease as also reported by Levykh (1940), Minev (1957), Rossouw (1959), Schanthorst (1960), Morrison (1961 & 1964), Malik et al. (1973) and Khan (1975). However, no infection on composites has been observed from April to September (Tables - 1-2), probably because

the temperature remains very high and relative humidity is very low. Similar seasonal fluctuations in disease development had been found by Levykh (1940), Deslandes (1954), Minev (1957), Rossouw (1959) and Schnathorst (1960).

In the absence of perfect stage, the powdery mildews infecting composites are identified on the basis of colour of the mycelium and conidial characters as suggested by Hirata (1942), Nour (1957), Clare (1958), Kable and Ballantyne (1963), Zaracovitis (1965), Blumer (1967), Jhooty (1967) and Mathur et al. (1971 & 1974). The above characters were taken into account for differentiation of the powdery mildews, it has been observed that E. cichoracearum infects Centaurea moschata, Cineraria sp. and Zinnia elegans as reported by Jain and Singh (1968), MacDonald (1939), Baker and Locke (1946) and Eliade (1975), in addition to these, Dahlia variabilis and Vernonia cinerea are the new hosts of this pathogen; S. fuliginea infects Carthamus tinctorius, Dimorphotheca sinuata and Helianthus annuus. These findings are in accordance with the observations of Jhooty (1965), Hirata (1966), Mathur et al. (1971) and Tanaka et al. (1987). Acroclinium sp., Chrysanthemum carinatum, Cosmos sulphonus and Xanthium strumarium are additional hosts to S. fuliginea. While Oidium spp., are observed on Ageratum conyzoides, Bellis perennis, Brachycome iberidifolia and Gazania splendens. These findings are supported by Blumer (1967), Eshed (1977), Hirata (1986) and Koike et al. (1988). In addition to these, Gamolepis tagetes is

also recorded as the host of Oidium sp. (Table - 3).

These findings are confirmed by several workers but some observations are in contrast to the earlier findings. Present study reveals that the pathogen of Acroclinium sp. is S. fuliginea rather than E. cichoracearum as reported by Jain and Singh (1968); Carthamus tinctorius and Xanthium strumarium are the hosts of S. fuliginea inspite of E. cichoracearum f.sp. Carthami and Oidium xanthemi respectively as studied by Milovtzova (1938); Saluja and Bhide (1964); Bhatnager and Kothari (1966).

Reports of S. fuliginea on Chrysanthemum carinatum and Helianthus annuus also been confirmed when the perithecia are collected on these hosts in nature (Table - 4). These observations are in accordance with the reports of Blumer (1967); Patil (1964), Patwardhen (1965) and Prasad et al. (1968). As the detailed studies of the pathogen indicate that the causal organisms on plants surveyed are S. fuliginea (7 plants), E. cichoracearum (5 plants) and Oidium spp. (5 plants) respectively at Aligarh (India). However, perithecium of S. fuliginea had been collected on C. carinatum and H. annuus, which confirms the identity of the pathogen on these hosts as S. fuliginea rather than E. cichoracearum. However, perfect stage of E. cichoracearum had not been collected on any of the composites so far under Indian conditions.

Results on host range studies indicate that the isolates of E. cichoracearum from C. moschata, Cineraria sp., D. variabilis

and Z. elegans infect Cineraria sp., C. moschata, D. variabilis, Lactuca sativa and Z. elegans amongst the cultivated composites (Table - 5) while these isolates fail to develop the disease on wild and non-composites (Tables - 6-7).

The isolates of S. fuliginea from Acroclinium sp., C. tinctorius, C. carinatum, C. sulphonus, D. sinuata, H. annuus and X. strumarium did not parasitize to the tested plants except their respective hosts, in addition Cacalia coccinia got infected from the X. strumarium isolate (Table - 8-10). Similarly the Oidium isolates from B. perennis, B. iberidifolia and G. splendens failed to develop symptoms on all tested plants (Tables - 11-13).

These findings are in accordance with the reports of Hirata (1986), Cineraria sp., D. variabilis and L. sativa are the additional hosts of E. cichoracearum under Indian conditions. Similar is the case of Acroclinium sp., C. tinctorius, C. carinatum for S. fuliginea and B. iberidifolia and G. tagetes for Oidium spp. respectively.

The isolates of E. cichoracearum from non-composites viz. Coccinia cordifolia and Benincasa hispida also failed to produce symptoms on composite plants (Tables - 14-16). This host specialization is in accordance with Miller and Barret (1931), Schmitt (1955), Chandra et al. (1981) and Akram and Perwez (1989), while contrary to the work reported by Reed (1908).

Conclusively the isolates E. cichoracearum from composites appear to be different from that of non-composites. The isolates of E. cichoracearum from composite plants viz. C. moschata, Cineraria sp., D. variabilis and Z. elegans infect Cineraria sp., C. moschata, D. variabilis, L. sativa and Z. elegans and not other composites. Hence we can conclude that there exists different strains of E. cichoracearum showing this type of specificity amongst different plants of Compositae. Similar results were obtained with the isolates of S. fuliginea and Oidium spp.

During varietal screening of cultivated composites, they were inoculated with the isolates of E. cichoracearum obtained from C. moschata, Cineraria sp., D. variabilis, V. cinerea and Z. elegans. It has been noticed that the variety of Cineraria sp. viz. single large superb mixed of Sutton's seed; D. variabilis vars. cactus mixed (N. Cooper) and local of Gaurav seed; L. sativa var. local of Punjab seed and Z. elegans vars. haageana hybrid (Sutton's seed), golden yellow, scarlet red and lilliput of Punjab seed proved to be highly susceptible to resistant against these isolates (Tables - 19, 20, 23 & 25).

In majority of the tests, the host response in glass house and field is the same. However, in case of D. variabilis vars. local was susceptible under glass house but resistant in field, whereas, cactus mixed was resistant in glass house and highly resistant to field conditions; L. sativa var. local was resistant in glass house but highly resistant in field conditions and

Z. elegans var. haagean hybrid was resistant in glass house but highly resistant under field conditions (Tables - 20, 23 & 25). Therefore, it is understandable that the glass house conditions are a bit controlled and more conducive for the development of powdery mildew rather than the field. In field there are many other factors which influence the development of the disease. Somewhat similar results were obtained by Delp (1954), Manson (1955), Yarwood (1957), Cole (1964 & 1966) and Schnathort (1965).

Earlier reports of E. cichoracearum and S. fuliginea on H. annuus creats some confusion about the definite identity of its pathogen. Patil (1964), Patwardhan (1965), Jhooty (1965) and Prasad et al. (1968) reported its pathogen as S. fuliginea while Patel et al. (1949), Pavgi and Upadhyay (1966) observed E. cichoracearum on H. annuus. Due to this controversy, a common host test on H. annuus was conducted and observed that the H. annuus is the common host of both the pathogens i.e. of S. fuliginea and E. cichoracearum under Indian climatic conditions (Table - 26).

Data concerning the effect of temperatures and relative humidities (Tables - 27-28) show that the temperature below 15°C or above 25°C and relative humidity below 90 percent do not favour the germination of conidia of E. cichoracearum from D. variabilis and Z. elegans. These observations are in accordance with the reports of Levykh (1940), Deslandes (1954), Minev (1957), Rossouw (1959), Schnathorst (1960), Morrison (1961 & 1964) and

Tafradzhiiski (1963). They observed that the germination of E. cichoracearum has an optimum temperature range as 17-20°C and optimum relative humidity with 95-100 percent. Further free water has been retarted the germination of conidia or even they failed to germinate, which confirm the findings of Corner (1935), Minev (1957), Schnathorst (1959), Morrison (1961 & 1964) and Tafradzhiiski (1963).

Similarly the development of powdery mildew has been maximum at 20°C and 100 percent relative humidity. At other temperatures and relative humidities, the development of powdery mildew was comparatively less. This shows that a moderate temperature and moisture favours the disease development. These are probably the reasons of high incidence of disease during October to late November and late January to March. Similar results had been obtained by Deslandes (1954), Minev (1957), Rossouw (1959), Schnathorst (1960) and Clark and Ayesuoffei (1967).

Conclusively, a question arises as to how the pathogen of powdery mildew perennates under tropical conditions is still in dilemma. The only possible explanation of the recurrence of the disease in plains of north India that there is either a mutual exchange of conidia from the hills to the plains or vice-versa or the discharge of ascospores from perithecia which have undergone longer period of maturation (Moseman et al., 1957). The work on these aspect is still in progress.

SUMMARY

During survey, the incidence and severity of powdery mildew has been studied on different members of the family Compositae at different localities in Aligarh and its adjoining areas throughout the year. There has been two flushes of powdery mildews on this family. One from January to March and other from October to December every year.

The powdery mildews of different members of Compositae have been identified as Erysiphe cichoracearum, Sphaerotheca fulginea and Oidium spp., mostly based on mycelial and conidial characters. Only on Helianthus annuus and Chrysanthemum carinatum, identity of the pathogen is confirmed on the basis of perithecial characters.

Host range studies reveals that the Cineraria sp. is susceptible to Cineraria sp., Dahlia variabilis and Zinnia elegans isolates of E. cichoracearum; however, D. variabilis is susceptible to D. variabilis and Z. elegans isolates and Lactuca sativa is susceptible with D. variabilis isolate of the same pathogen, both in glasshouse as well as in the field conditions.

The isolate of S. fuliginea from Xanthium strumarium produced symptoms on Cacalia coccinia.

The Oidium spp. obtained from three composite plants viz. O_1, O_2 and O_3 fail to produce symptoms on other members of the same family.

The isolates of E. cichoraccarum from Coccinia cordifolia and Benincasa hispida (Cucurbitaceae) fail to parasitize the composite plants.

So we can say that the isolates of E. cichoracearum from composites appear to be different from that of non-composites. However, isolates of E. cichoracearum from composites gave different response in members of Compositae, so it can be concluded that various strains of E. cichoracearum exists, showing specificity amongst the composites.

During varietal screening Var. of Cineraria sp. viz. large single superb mixed is highly susceptible to resistant to Erysiphe cichoracearum from Cineraria sp., D. variabilis and Z. elegans; two Vars. of D. variabilis viz. cactus mixed is resistant to D. variabilis and Z. elegans isolates of E. cichoracearum and Var. local is highly susceptible to resistant against Cineraria sp., D. variabilis and Z. elegans isolates. In addition Vars. of Z. elegans viz. haageana hybrid, scarlet red and lilliput are highly susceptible to resistant against isolates obtained from D. variabilis and Z. elegans respectively.

Earlier reports indicated both the pathogens i.e. E. cichoracearum and S. fuliginea on H. annuus. These reports are confirmed by a common host test on H. annuus under Indian climate.

The powdery mildew disease appeared at 15-25°C and 81-100 percent relative humidities, but maximum intensity of the disease has been observed at 20°C and 100 percent relative humidity.

Conidial germination is initiated after 12 hours of incubation, the optimum temperature for the germination of conidia of E. cichoracearum ranged between 15-25°C. Highest germination of conidia of E. cichoracearum took place at 95-100 percent relative humidity but they failed to germinate in free water.

The relative humidity does not appear to exert much influence on the development of disease at optimum temperature but temperature appeared to a deciding factor as disease developed within 6 days at optimum temperature irrespective to relative humidity.

The perithecia obtained from C. carinatum and H. annuus fails to discharge the ascospores even they are subjected to various treatments. .

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* - original not seen.

APPENDIX - I

List of Abbreviations:

Abst.	Abstract
cm	Centimeter
et al.	et alu (= and others)
Fig.	Figure
i.e.	Id est (= that is)
p	Page
pp	Pages
um	micro
viz.	Videlicet (= namely)
sp.	species
/	per

APPENDIX - II

Species of different plants	Name of the suppliers
Acroclinium sp.	
Var. special mixture	Sutton's seed, Calcutta.
Var. splendens mixed	Sutton's seed, Calcutta.
Arctotis sp.	
Var. grandis hybrid	Sutton's seed, Calcutta.
Var. special hybrid	Sutton's seed, Calcutta.
Aster sp.	
Var. california giants mixed	N. Cooper, Poona.
Var. powder puff mixed	N.Cooper, Poona.
Var. giant mixed	Punjab seed, Aligarh.
Var. local	Gaurav seed, Aligarh.
Calendula officinalis	
Var. orange king	Sutton's seed, Calcutta.
Var. lemon queen	Sutton's seed, Calcutta.
Var. orange coronet	Sutton's seed, Calcutta.
Var. art shades	Sutton's seed, Calcutta.
Var. double mixed	N. Cooper, Poona.
Var. fiesta gitana	Sutton's seed, Calcutta.
Var. double mixed$_2$	Punjab seed, Aligarh.
Var. local	Gaurav seed, Aligarh.
Carthamus tinctorius	
Var. kinko	Sutton's seed, Calcutta.
Chrysanthemum carinatum	
Var. coronarium mixed	N. Cooper, Poona.
Var. fine mixed	Punjab seed, Aligarh.
Var. local	Gaurav seed, Aligarh.

Cineraria sp.	
Var. large single superb mixed	Sutton's seed, Calcutta.
Cosmos sulphonus	
Var. alipore beauty	Sutton's seed, Calcutta.
Var. klondyke mixed	Sutton's seed, Calcutta.
Var. single mixed	Sutton's seed, Calcutta.
Var. double mixed	Sutton's seed, Calcutta.
Var. tall orange	N. Cooper, Poona.
Var. purity	N. Cooper, Poona.
Var. cosmos mixed	Punjab seed, Aligarh.
Var. pinkie	N. Cooper, Poona.
Var. double crosted mixed	N. Cooper, Poona.
Var. local	Gaurav seed, Aligarh.
Coreopsis sp.	
Var. dwarf mixed	Sutton's seed, Calcutta.
Var. tall mixed	Sutton's seed, Calcutta.
Var. picta	Sutton's seed, Calcutta.
Var. grandiflora double	N. Cooper, Poona.
Dahlia variabilis	
Var. double mixed	Punjab seed, Aligarh.
Var. unwins dwarf mixed	N. Cooper, Poona.
Var. large fld. mixed	N. Cooper, Poona.
Var. giant double mixed	Sutton's seed, Calcutta.
Var. cactus mixed	N. Cooper, Poona.
Var. local	Gaurav seed, Aligarh.
Dimorphotheca sinuata	
Var. glistening white	Sutton's seed, Calcutta.
Var. special mixture	Sutton's seed, Calcutta.
Var. giant orange	Sutton's seed, Calcutta.
Var. mixed	Punjab seed, Aligarh.

Gaillardia sp.	
Var. double mixed	N. Cooper, Poona.
Var. lorenziana single mixed	N. Cooper, Poona.
Var. lollypop yellow	Sutton's seed, Calcutta.
Gazania splendens	
Var. sunshine hybrid mixed	Sutton's seed, Calcutta.
Var. hybrid mixed	Sutton's seed, Calcutta.
Helianthus annuus	
Var. double chrysanthemum fld.	Sultan Garden, Kashmir.
Var. sungold dwarf	N. Cooper, Poona.
Var. chrysnathemum fld. mixed	N. Cooper, Poona.
Var. sunburst	Sutton's seed, Calcutta.
Var. double orange	Sutton's seed, Calcutta.
Var. dwarf sungold	N. Cooper, Poona.
Var. bronze hybrid	Punjab seed, Aligarh.
Var. double sungold	Punjab seed, Aligarh.
Var. japanees single maniature	Punjab seed, Aligarh.
Var. $local_1$	Gaurav seed, Aligarh.
Var. $local_2$	Sultan Garden, Kashmir.
Helichrysum bracteatum	
Var. large fld. mixed	Sutton's seed, Calcutta.
Var. double mixed	Punjab seed, Aligarh.
Var. choice mixed	N. Cooper, Poona.
Lactuca sativa	
Var. paris whitecos	N. Cooper, Poona.
Var. ice berg	N. Cooper, Poona.
Var. local	Punjab seed, Aligarh.
Tagetes erecta	
Var. double mixed	Sultan Garden, Kashmir.
Var. french petite mixed	Sutton's seed, Calcutta.

Var. giant double african mixed	Sutton's seed, Calcutta.
Var. giant double lemon	Sutton's seed, Calcutta.
Var. giant double orange	Sutton's seed, Calcutta.
Var. french red brocade	Sutton's seed, Calcutta.
Var. sunset giants mixed	Sutton's seed, Calcutta.
Var. cupid yellow	Poocha seed, Poona.
Var. dwarf harmony	Poocha seed, Poona.
Var. hybrid gee whiz lemon	Sutton's seed, Calcutta.
Var. tall african mixed	N. Cooper, Poona.
Var. french dwarf mixed	N. Cooper, Poona.
Var. crackerjack	N. Cooper, Poona.
Var. chrysanthemum fld. mixed	N. Cooper, Poona.
Var. local	Sultan Garden, Kashmir.

Zinnia elegans

Var. giant hybrid mixed	N. Cooper, Poona.
Var. dahlia fld. polar bear	N. Cooper, Poona.
Var. dahlia fld. scarlet flame	N. Cooper, Poona.
Var. dahlia fld. purple prince	N. Cooper, Poona.
Var. elegans choice mixed	N. Cooper, Poona.
Var. dahlia fld. mixed envy, green	Poocha seed, Poona.
Var. giant dahlia fld. mixed	Sultan Garden, Kashmir.
Var. dahlia fld. royal purple	Poocha seed, Poona.
Var. dahlia fld. golden state	Poocha seed, Poona.
Var. giant dahlia illumination	Poocha seed, Poona.
Var. dahlia fld. golden dawn	N. Cooper, Poona.
Var. dahlia fld. crimson monarch	N. Cooper, Poona.
Var. dahlia fld. dream	N. Cooper, Poona.
Var. equisite	N. Cooper, Poona.
Var. dahlia fld. oriole	N. Cooper, Poona.
Var. california giant mixed	N. Cooper, Poona.
Var. lilliput mixed	N. Cooper, Poona.
Var. rich salmon rose	Sutton's seed, Calcutta.
Var. giant double yellow	Sutton's seed, Calcutta.

Var. giant double orange	Sutton's seed, Calcutta.
Var. persian carpet	N. Cooper, Poona.
Var. linearis orange	N. Cooper, Poona.
Var. haageana hybrid	Sutton's seed, Calcutta.
Var. scarlet red	Punjab seed, Aligarh.
Var. lilliput	Punjab seed, Aligarh.
Var. golden yellow	Punjab seed, Aligarh.
Var. double yellow	Gaurav seed, Aligarh.
Var. white	Punjab seed, Aligarh.
Var. giant double white	Sutton's seed, Calcutta.
Var. dahlia fld. mixed	N. Cooper, Poona.